L. W. Ross

ELEMENTS OF COMMUNICATION

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INCORPORATED
NEW YORK, N. Y.

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CHAPTER I - TRANSMISSION OF SOUND

The problem of transmitting sound by means of an electric current resolves itself into finding some means of causing an electric current to vary in response to sound waves. We all know that sound consists of vibrations or waves travelling outward in all directions from the source. If, then, we can find some device which will respond to these sound waves which can be linked to a source of electricity in such a way as to vary the flow of electrical current in response to these sound waves, we have mastered the fundamental scheme for transmitting sound by electricity.

Fig. 1 and 2 are diagrams which illustrate the disturbance which takes place in the air when a diaphragm vibrates. The circles in these figures represent the molecules which compose the air. As the surface of the diaphragm moves toward the air molecules, they are pushed away, and as the surface moves away from the molecules they are drawn back toward it. The vibration of the diaphragm thus causes the molecules to move back and forth following the motion of the surface of the diaphragm. This motion of the molecules is passed on to the adjacent molecules which in turn pass it on to their adjacent molecules with the result that the disturbance travels radially away from its source. When the vibration occurs within a range of from about 30 to about 10000 times a second this motion of the molecules is called a sound wave.

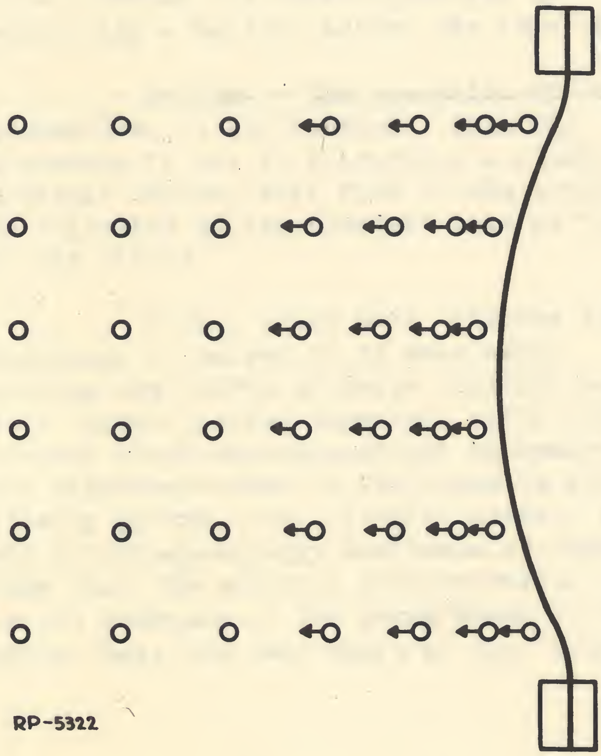

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Fig. 1

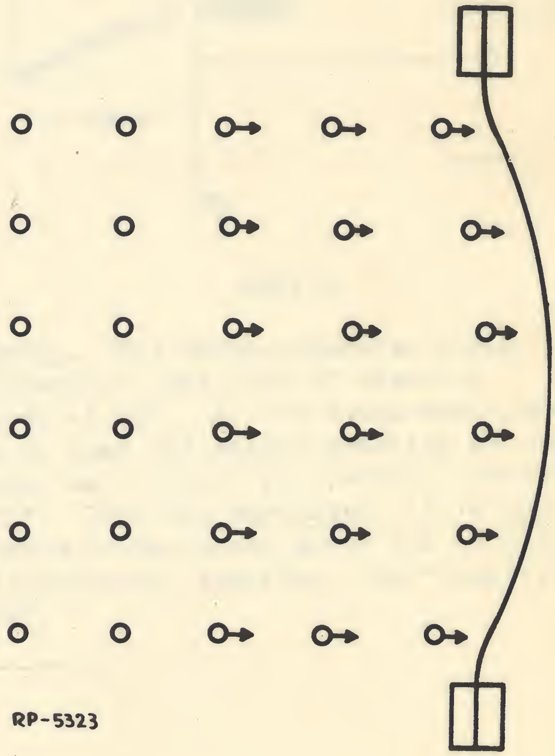

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Fig. 2

CHAPTER I (Continued)

When the foregoing procedure is reversed, that is, when a sound wave encounters a diaphragm, the diaphragm under proper circumstances will respond to the sound waves and be set in motion. When the molecules rush up against some other surface, they exert a force which tends to push it away, and when they retire from it they tend to draw it with them, and if the surface is free to move, it will be caused to vibrate in the same manner as the surface which produced the sound wave. Thus, a vibrating body can produce sound waves in the surrounding medium and, conversely, sound waves in the surrounding medium can cause a body to vibrate. It is plain that if the vibration of a body under the influence of sound waves can be transferred to a distant body, similar sound waves will be generated at the distant point and in effect the sound will be transferred from one point to another. This principle is employed in the telephone by causing the motion of a sensitive diaphragm in the transmitter to be transferred by electrical means to a diaphragm in a distant receiver.

In Fig. 3 are illustrated the essential parts of the ordinary transmitter. These consist principally of a diaphragm and two discs, one of which is attached to the diaphragm, the space between them being filled with a quantity of carbon granules. An electric current is caused to flow from one disc to the other through the carbon granules by connecting a battery across the terminals.

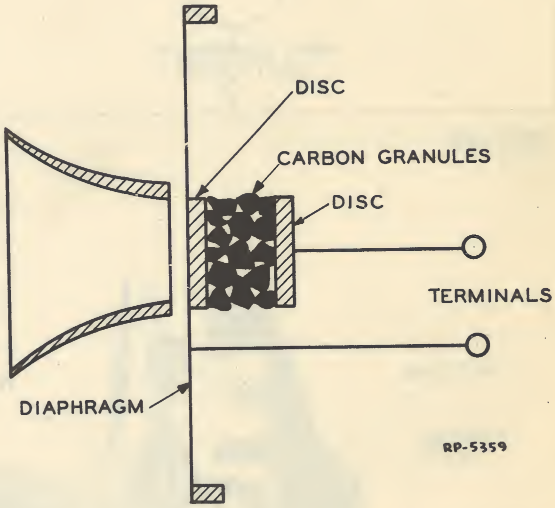


Fig. 3

In Fig. 4 the operation of the transmitter is illustrated. When the diaphragm is not in vibration, a steady electric current will flow in the circuit as indicated by the straight line at "A" in the figure.

When a sound wave strikes the diaphragm it causes it to move back, packing the carbon granules together more tightly. The carbon granules being more tightly packed together, offer less resistance to the flow of electric current which correspondingly increases as shown at "B". As the sound wave recedes the diaphragm moves in the opposite direction so that the carbon granules are more loosely packed, thus offering greater resistance to the flow of electric current which correspondingly decreases as shown at "C". From the foregoing, it is apparent then that the electric current varies in response to the sound waves and is modeled in the likeness of the sound waves so that, figuratively speaking, the "electrical waves" have the same shape as the "sound waves".

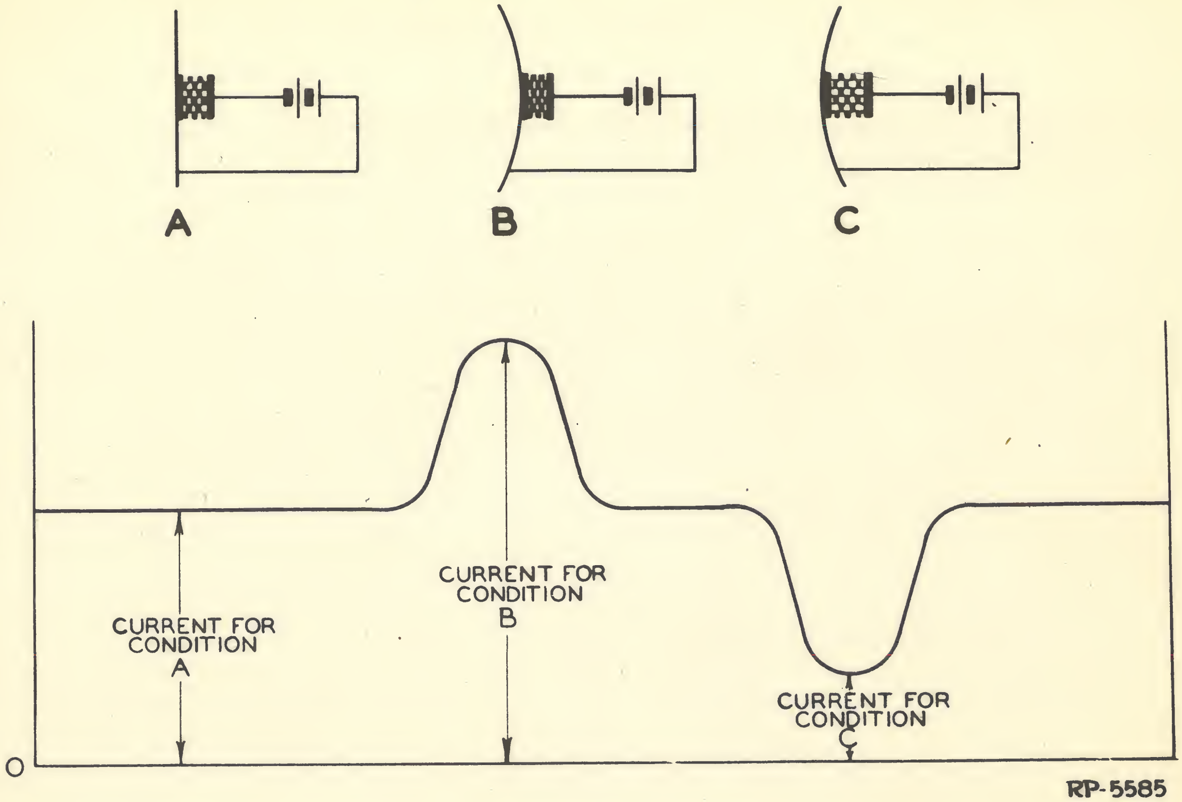
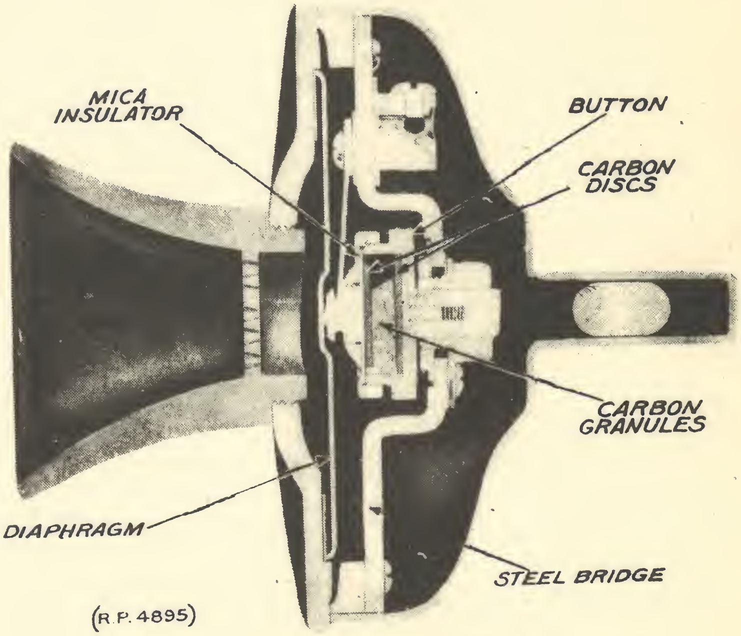


Fig. 4

The actual construction of a transmitter is shown in Fig. 5. The carbon granules referred to in Fig. 3 are contained in a chamber known as a "button" which is solidly fastened to a steel bridge. The two surfaces of the chamber in the button are made of highly polished carbon, the front one of which is attached to a mica disc in such a way that it is free to move under the influence of the diaphragm which rests against the head of the button.



CROSS SECTION OF TRANSMITTER

Fig. 5

CHAPTER I (Continued)

We now have a means for varying an electric current in response to sound waves and our next problem is to provide some device for reproducing the sound waves from the varying electric current. The method by which this is accomplished with an ordinary receiver will be described.

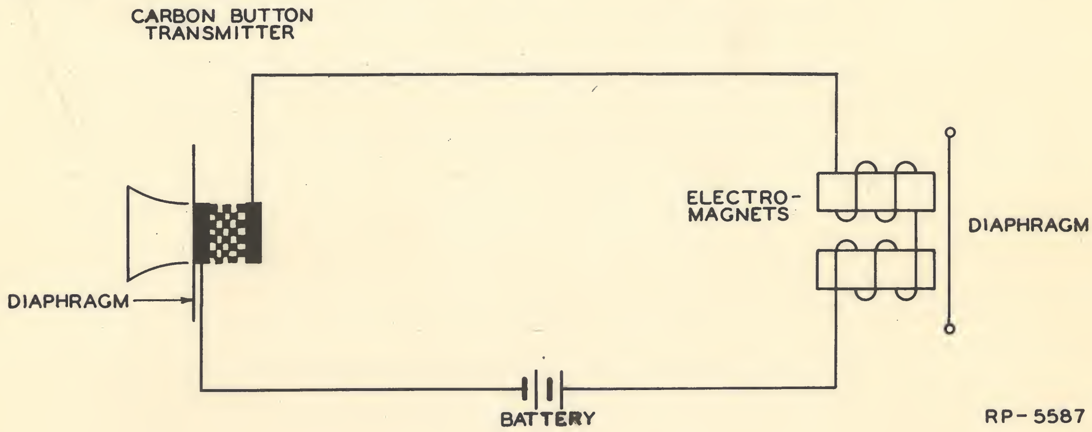


Fig. 6

In Fig. 6 a transmitter and receiver are shown connected in series with a battery. In this figure one of the transmitter discs between which the carbon granules are located, is connected to a battery and the other side of the battery is connected to two coils known as electro-magnets, from which the circuit is completed to the other disc of the transmitter. The current flowing in the coils of the electro-magnet produces a magnetic effect in each coil which exerts a pull on the diaphragm of the receiver. This is exactly the same effect that is produced by the current flowing in the coils of a telegraph sounder shown in Fig. 7.

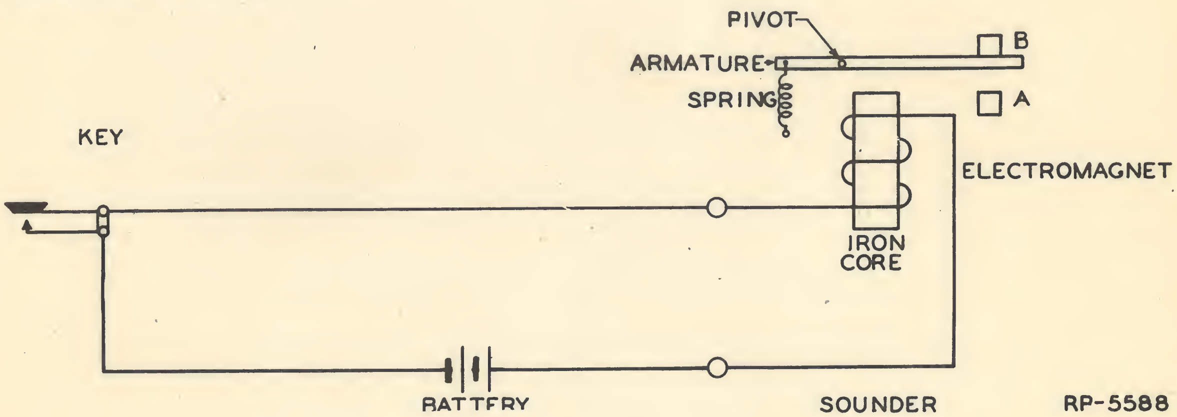


Fig. 7

When the telegraph key is closed the circuit is completed, allowing a current to flow in the coils of the electro-magnet of the sounder which produces a magnetic effect, pulling the armature of the sounder from point "B" to point "A" in the figure.

CHAPTER I (Continued)

In a receiver the electro-magnet exerts a pull upon the diaphragm in the same manner, the amount of pull varying in proportion to the amount of the current in the circuit. Thus, when the current is greatest the diaphragm will be deflected farthest from the normal position and, as the current decreases, the diaphragm will tend to come back to its normal position. In this way the receiver diaphragm vibrates in response to the fluctuations of the electric current.

It should be noted that the electro-magnet exerts a pull upon the diaphragm at all times although the amount of this pull varies as the current increases and decreases. In actual practice it is not convenient to connect two telephones as shown in Fig. 6, an induction coil being inserted between the transmitter and the receiver, as illustrated in Fig. 8.

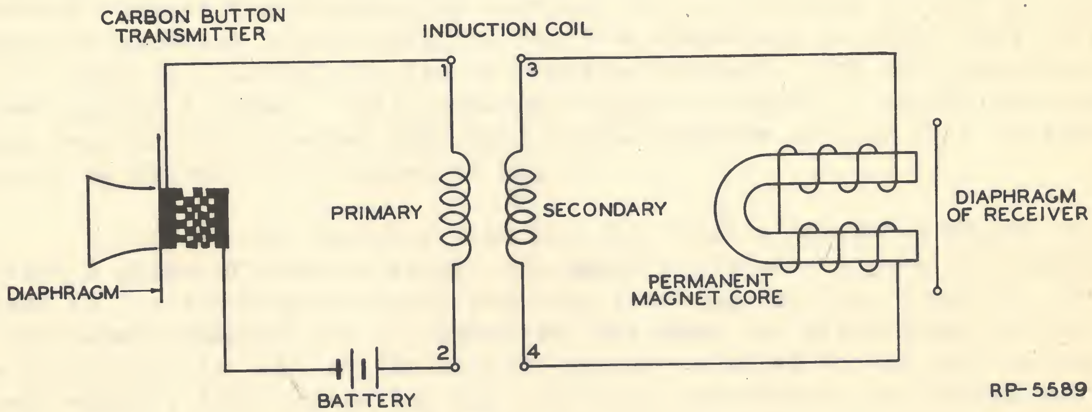


Fig. 8

This has the effect of allowing only the varying portion of the electric current to reach the receiver, that is, there is no continuous pull exerted on the receiver diaphragm by the electro-magnet. The varying current flows in the winding of the induction coil connected to the transmitter called the "primary" winding and this varies as previously described in connection with Fig. 6. So long as there is a steady current flowing in the primary winding, there is no effect on the other or "secondary" winding. Any change in the current through the primary winding, however, will produce a current in the secondary winding. If the current in the primary winding is increasing, the current in the secondary winding will be in one direction, and when the primary current decreases, the current in the secondary winding will be in the opposite direction. This current in the secondary winding, which alternately reverses its direction with the increasing and decreasing of the current in the primary winding, is known as "alternating current". An alternating current could be illustrated graphically by moving the zero line shown in Fig. 4 up to the line which denotes the amount of steady current flowing in the circuit as indicated at "A". This is illustrated in Fig. 9.

CHAPTER I (Continued)

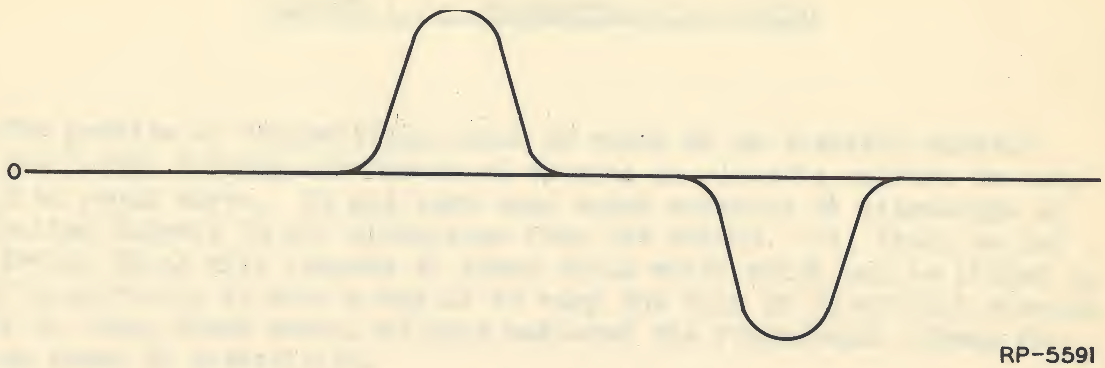


Fig. 9

Inasmuch as there is no current in the electro-magnet coils of the receiver, except the alternating current, it is necessary to provide some means for exerting a pull upon the receiver diaphragm in order that this pull can be made to fluctuate by the alternating current. For this purpose a permanent magnet is used. This permanent magnet is merely a magnetized piece of steel bent so that the two ends come close together similar to a horseshoe magnet, as already illustrated in Fig. 8.

You are all familiar with the fact that a horseshoe magnet will attract a piece of iron or steel. In exactly the same manner the permanent magnet of the receiver attracts the iron diaphragm of the receiver. The coils of the electro-magnet are so connected that when the alternating current is in one direction the pull of the electro-magnet is added to the pull of the permanent magnet, thus increasing the total pull exerted on the diaphragm. When the current reverses, the pull of the electro-magnet is opposing the pull of the permanent magnet so that less pull is exerted on the receiver diaphragm. Therefore, as the alternating current through the electro-magnet reverses its direction, the diaphragm is caused to move back and forth.

The permanent magnet is required due to the fact that the electro-magnet exerts a pull on the diaphragm regardless of the direction in which the current is flowing: that is, it does not pull the diaphragm when the current is flowing in one direction and push the diaphragm when it is flowing in the opposite direction. This is illustrated graphically in Fig. 10.

The receiver is shown with a single winding electro-magnet for the sake of simplicity, in one case with a soft iron core which has no magnetic effect but merely increases the effect of the electro-magnet, and in the other case with a permanent magnet. The resultant sound wave originating in response to the receiver having the permanent magnet conforms to the alternating current wave whereas the other does not. Inasmuch as the alternating current has the same shape as the variations in the direct current produced by the transmitter, the receiver diaphragm will vibrate in a similar manner to the vibrations of the transmitter diaphragm.

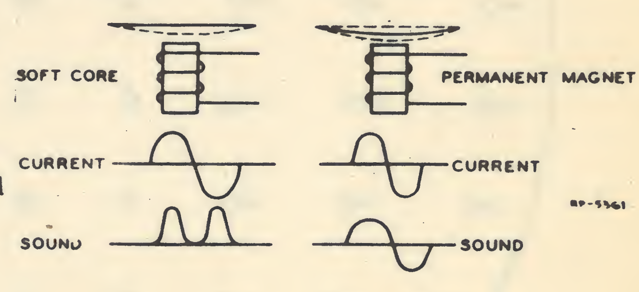


Fig. 10

LESSON I (continued)

In Fig. 11 is a diagram showing schematically the construction of a receiver, and in Fig. 12 is shown a cross section of a standard instrument with the essential parts clearly marked.

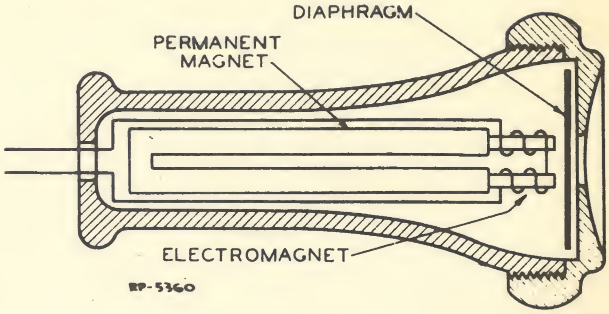
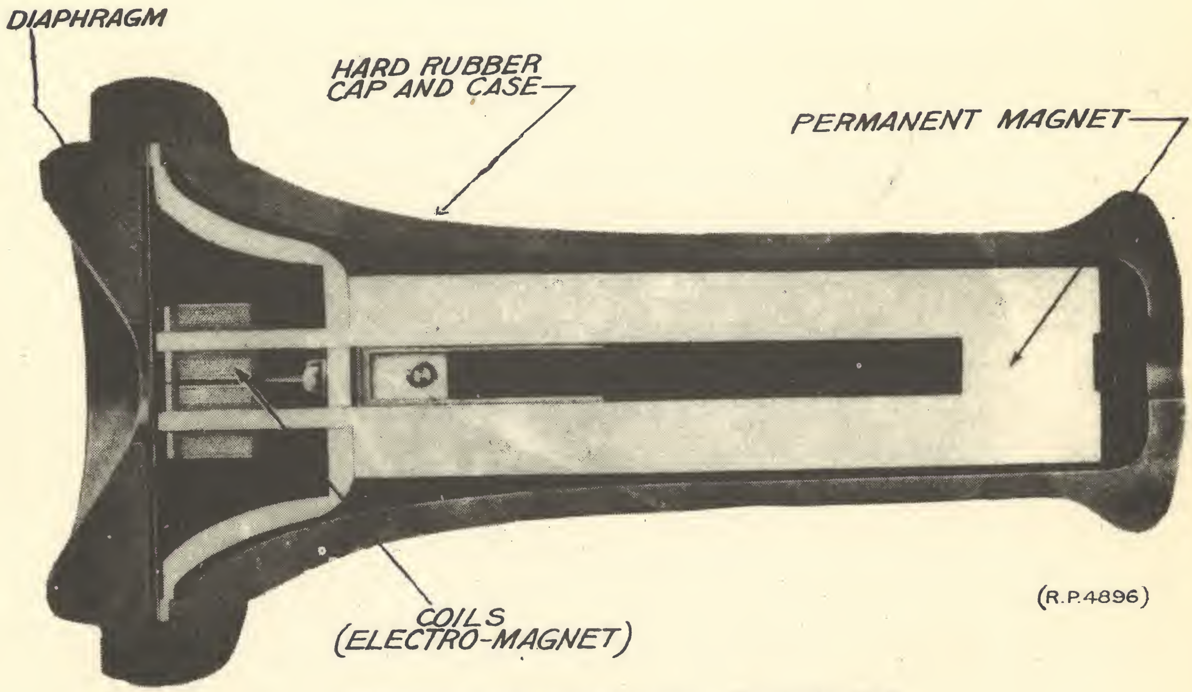


Fig. 11



CROSS SECTION OF RECEIVER

CHAPTER II - THE SUBSCRIBER'S TELEPHONE

In order that two people may carry on a conversation over the telephone it is, of course, necessary to transmit speech in both directions. This can very easily be accomplished by the proper combination of the transmitting and receiving devices we have already considered. Such an arrangement is shown in Fig. 13.

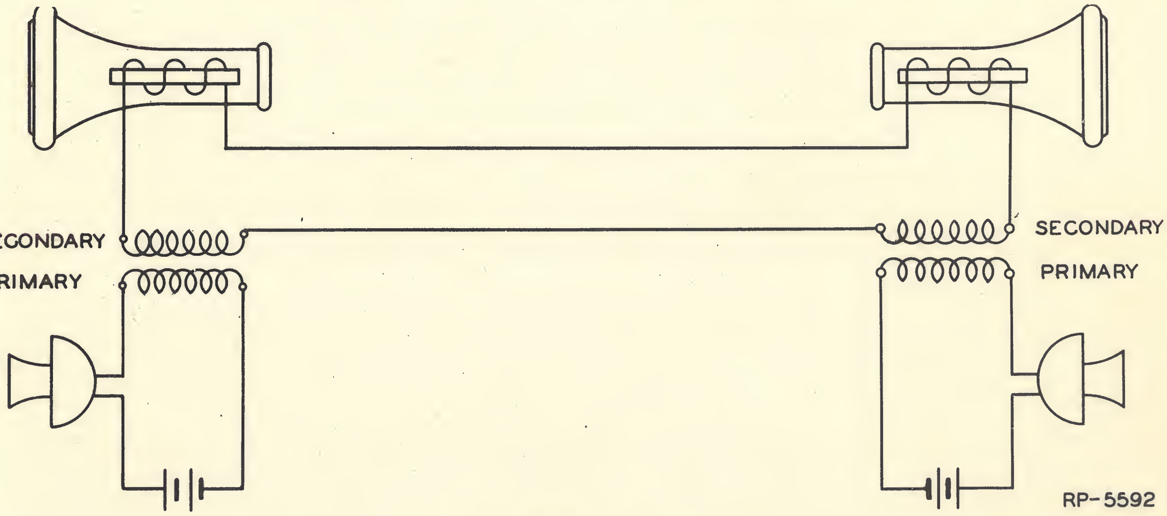


Fig. 13

Each transmitter has in series with it a battery and the primary of an induction coil, the secondary windings of which are connected in series with the line and the two receivers. A sound wave varying the diaphragm of one of the transmitters varies its resistance, thereby fluctuating the current, and these fluctuations create in the secondary of the induction coil, an alternating current which flows through the home receiver and the distant receiver in series. The alternating current flowing through the home receiver repeats the spoken word and we recognize this as "side tone". The same current flows through the distant receiver thereby accomplishing sound transmission. Transmission in the opposite direction takes place in the same way when a subscriber speaks into the transmitter at the other end of the line. Such a scheme is seldom used in actual practice except in very small telephone systems or for rural subscribers. The more common arrangement employs a battery located in the central office to supply all subscribers instead of having a battery in each telephone.

The circuit of a subscriber's telephone for use with a battery located in the central office, or common battery, as it is called, is somewhat different from the circuit we have just considered. The fundamental arrangement for a single line is shown in Fig. 14. This circuit contains a new piece of apparatus that we have not previously considered which is the condenser. A condenser is merely a gap in an otherwise continuous circuit, and in telephone practice this piece of apparatus usually consists of two pieces of tin foil separated by paper insulation so that there is no direct connection from one piece of tin foil to

CHAPTER II (continued)

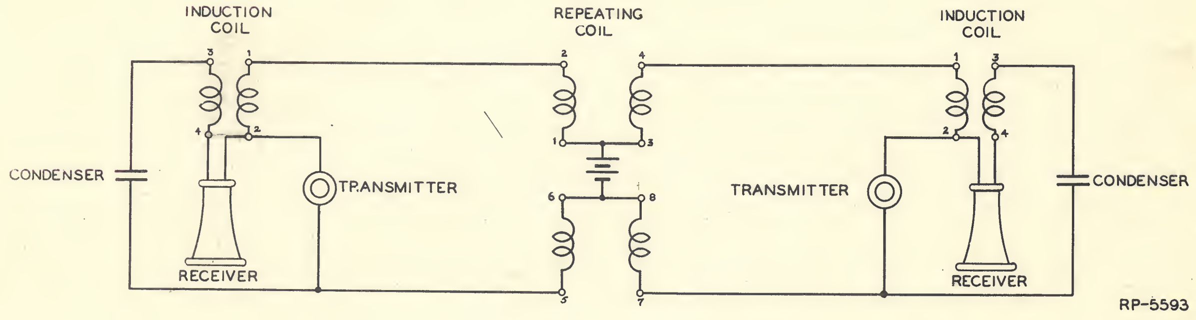


Fig. 14

another. However, when a battery is connected to the two sides of a condenser, as shown in Fig. 15, a momentary current will flow in the circuit until the condenser has accumulated as much electricity as the capacity of the two plates will allow. When this stage has been reached, the condenser is said to be "charged": the plate which is connected to the positive side of the battery has a positive charge, and the plate connected to the negative side of the battery has a negative charge. If we now disconnect the condenser from the battery, the condenser will be left in a charged condition.

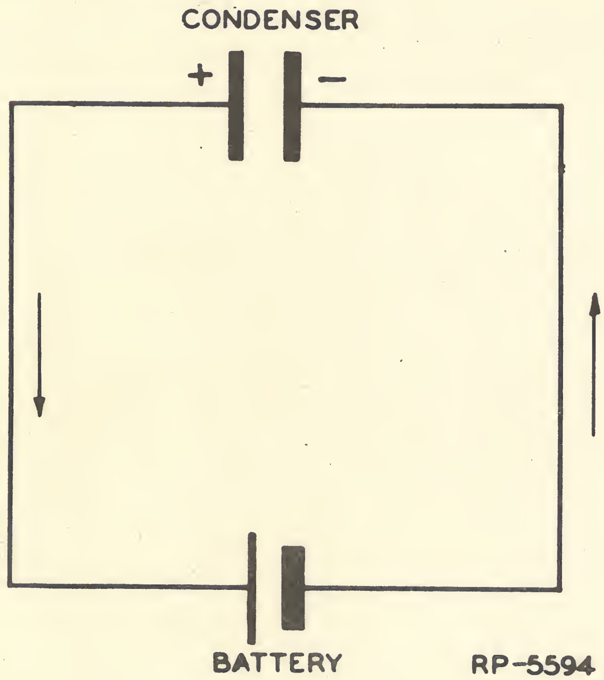


Fig. 15

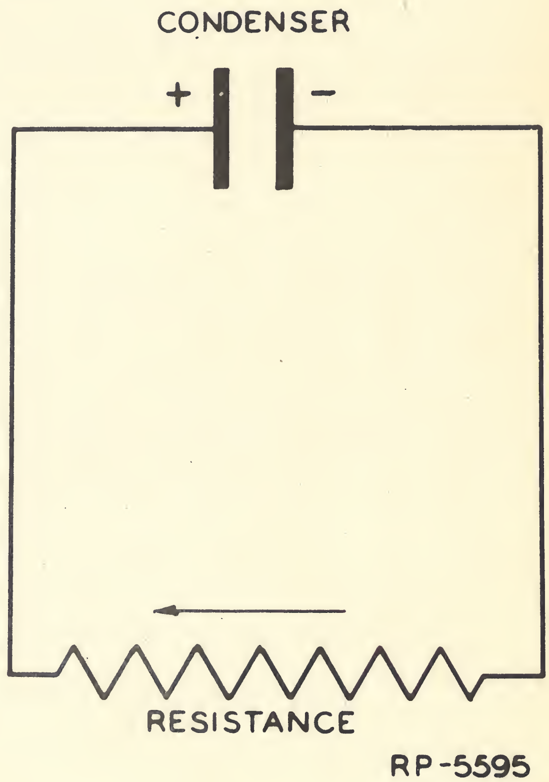


Fig. 16

When the two sides of the condenser are connected together by means of a resistance, as shown in Fig. 16, a flow of current will take place from one plate to another through the resistance, the negative charge on the one

plate neutralizing the positive charge on the other plate, and the condenser will be discharged.

The action which takes place when a condenser is connected to a source of alternating current is of particular interest in telephone work because this is the application to which it is usually put in practice. Under this condition the condenser receives a charge when the current is in one direction and discharges when the current reverses. Inasmuch as the charge and discharge of the condenser requires a flow of current alternately in reversed directions, the current flowing in the circuit becomes equivalent to an alternating current so that in practice the alternating current flows in the circuit much the same as though there were no condenser present in the circuit at all. It should be remembered that while in effect a condenser allows the passage of an alternating current, it acts as an insulator to steady currents as this principle is made use of in numerous ways in telephone circuits. A typical commercial condenser is shown in Fig. 17.

Before taking up a discussion of the circuit of the subscriber's telephone, let us discuss briefly the repeating coil. This coil is essentially the same as an induction coil which we have already considered. The main difference between this coil and the induction coil is its construction. A repeating coil is wound on a continuous iron core like a doughnut, technically described as toroidal. A picture of one of these coils with the cover removed to show the construction is shown in Fig. 18. There are actually four windings on these coils although for our purposes in discussing the theory of operation, coils marked 1, 2, and 5, 6, may be considered as one coil: for example, the primary and coils marked 3, 4, and 7, 8, may be considered as the other coil, or the secondary. We should not, however, consider these two coils as primary and secondary in the same way that they were thought of in connection with the induction coil as the action of the coil is reverse with the direction of conversation, the winding which forms the secondary sometimes being the primary, and vice versa.

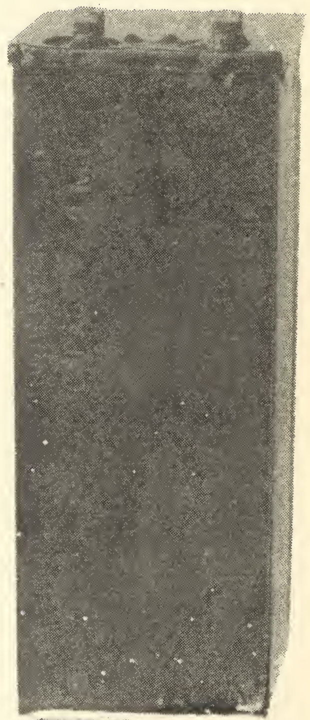


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Fig. 17

The action of the circuit given in Fig. 14 may now be described. The battery shown connected to the windings of the repeating coil supplies a current which flows through one winding of the repeating coil, transmitter, one winding of the induction coil, one winding of the repeating coil, and back to the battery. When the subscriber speaks into the transmitter a fluctuating current is created in this circuit in exactly the same manner as has already been described. The arrangement of this circuit, however, is such that a second action takes place in this case. The increasing and decreasing direct current alternately charges and discharges the condenser in the circuit through the receiver, one winding of induction coil, condenser, back to the transmitter. This charging and discharging of the condenser is in effect an alternating current

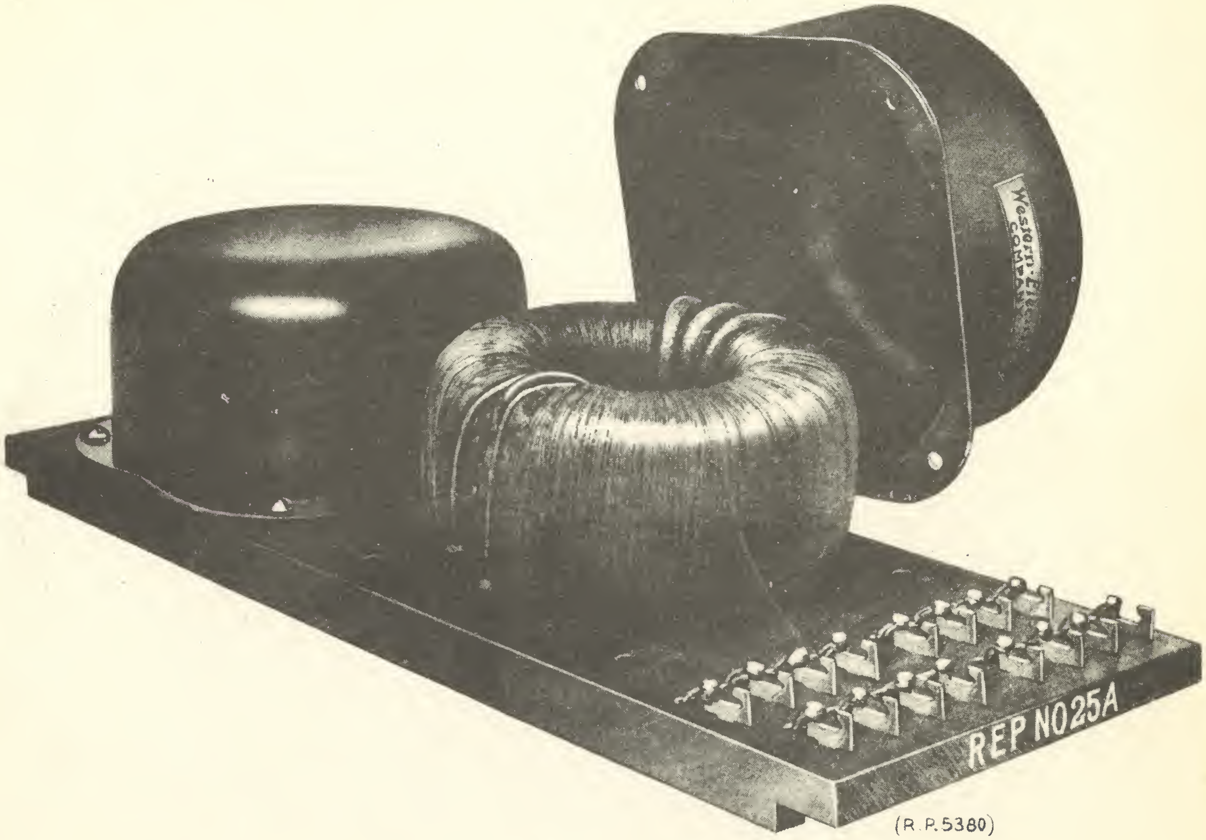


Fig. 18

flowing in windings 3, 4, of the induction coil and producing an alternating current in windings 1, 2, of the induction coil which flows out over the line through the windings of the repeating coil, the battery, and back to the transmitter. This alternating current creates another alternating current of the same characteristics in windings 3, 4, 7, 8, of the repeating coil which creates an alternating current in windings 3, 4, of the induction coil in the other subscriber's telephone. Inasmuch as the receiver in the second telephone is in series with windings 3, 4, of the induction coil in that telephone, the sound is reproduced. The reverse of this action takes place when a subscriber speaks into the transmitter at the other subscriber's station.

A complete subscriber's telephone circuit is shown in Fig.19. From this figure it will be clear why the condenser which we have previously referred to is required. The bells for signalling the subscriber are connected across the two windings

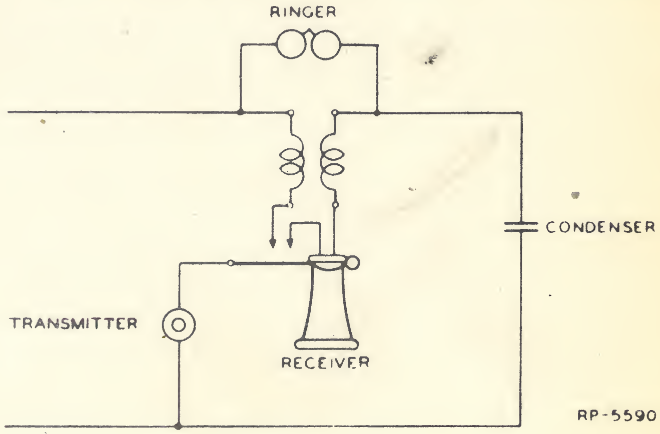


Fig. 19

of the induction coil, thus providing a path for the current from the battery to flow through the subscriber's telephone if it were not due to the fact that the circuit is open to steady currents at the condenser when the receiver is on the hook. If this condenser were not used, a current would flow continually in the subscriber's circuit which would be a wasteful use of the central office battery and, as we shall see later, would interfere with certain signalling operations.

Before taking up a consideration of the signalling arrangements, let us consider why the repeating coil was used in the circuit. Suppose, for example, that the coil had been omitted and a certain amount of resistance added, as illustrated in Fig. 20, we would still have a perfectly good working arrangement. The

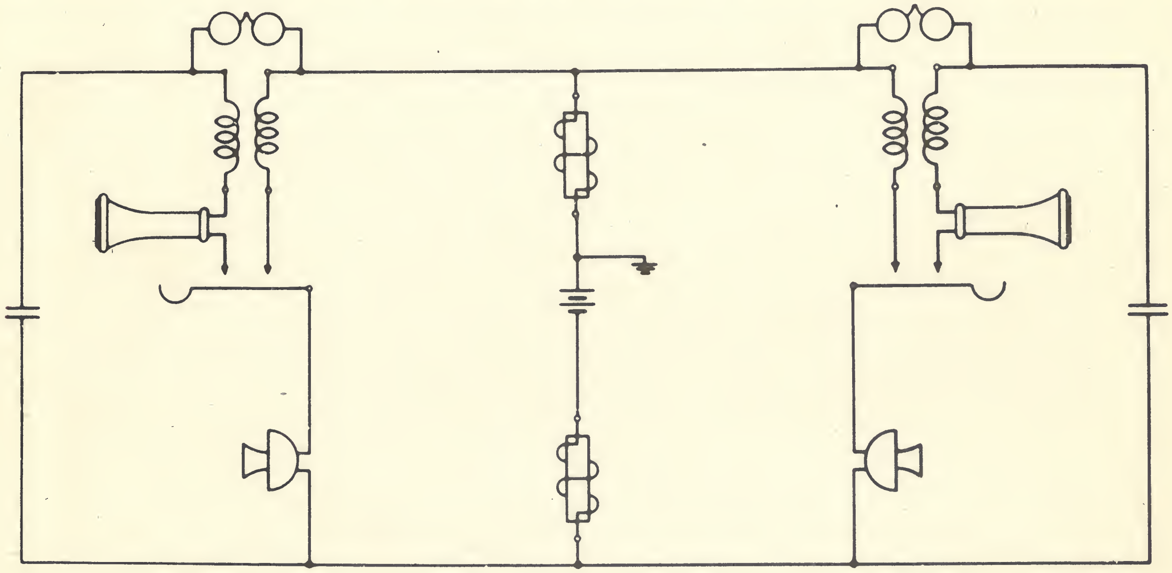


Fig. 20

difficulty with such a scheme, however, is that when two lines are connected together, one of which has a very low resistance and the other a very high resistance, the one having the lower resistance will draw most of the current while the higher resistance line will get very little. By using repeating coils, each line is entirely separated, thus eliminating this difficulty. The other scheme, however, is used to some extent in certain private branch exchanges where practically all the telephones are in the same building and the difference in the resistance of the subscriber's loop is negligible so that each telephone transmitter receives about the same supply of current.

We are now ready to consider the arrangements made for signalling the subscriber. In order to understand the operation of the ordinary ringer, we must consider further some of the characteristics of permanent magnets and electromagnets. You are all familiar with the fact that a compass will point north. The operating mechanism which causes the compass to do this is a permanent magnet balanced on a needle so that the two ends are free to swing about. One end of the magnet points north and the other end south. The end which points north is known

as the north pole and the end which points south, the south pole. Any permanent magnet exhibits this characteristic. Even a horseshoe magnet, in which the two ends have been brought close together, has this property although, due to the fact that it has been bent into the shape of a horseshoe, it is not practical to use it as a compass.

A single coil electro-magnet also exhibits these characteristics and, further, it is possible to determine by the direction of the flow of current in the coil which end of the magnet is the north pole and which is the south pole. The rule is illustrated in Fig. 21. To determine the north pole, place the fingers of the right hand around the coil in the direction in which the current is flowing, and the end of the magnet toward which the thumb is pointed is the north pole. When the current is reversed, the poles are reversed.

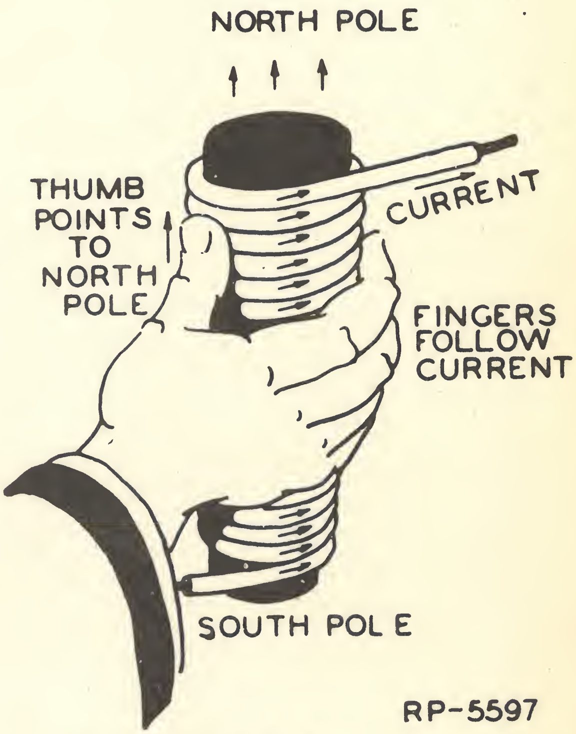


Fig. 21

The next property of a magnet which we should bear in mind is that the unlike poles attract each other and that the like poles repel. In other words, if we have two permanent magnets, the north pole of one will attract the south pole of the other, while if two south poles or two north poles are brought together, they will repel each other.

We are now ready for an explanation of the operation of the ringer used to signal a subscriber. In Fig. 22 is shown diagrammatically an ordinary ringer. Here we find the combination of a permanent and electro-magnet. The permanent magnet and electro-magnet establish two south poles (S-S), and by inductive effect make the two ends of the armature north poles (N-N). The center of the armature is consequently a south pole. In other words, the armature is a piece of soft iron with three poles, one in the center and one at each end induced by the action of the permanent magnet. The biasing spring holds the armature in a fixed position. Now suppose an impulse of current flows through the coils in the direction shown by the arrow. The magnetism set up by the

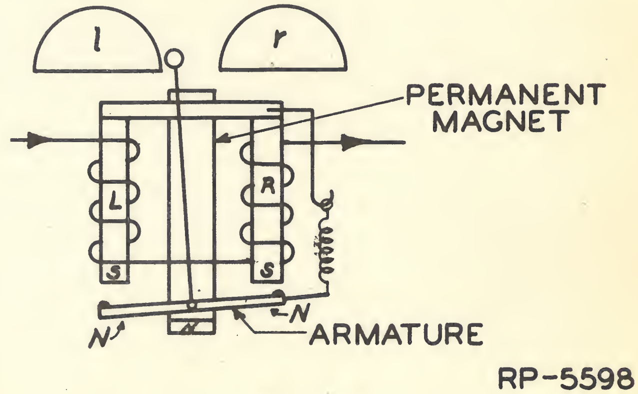
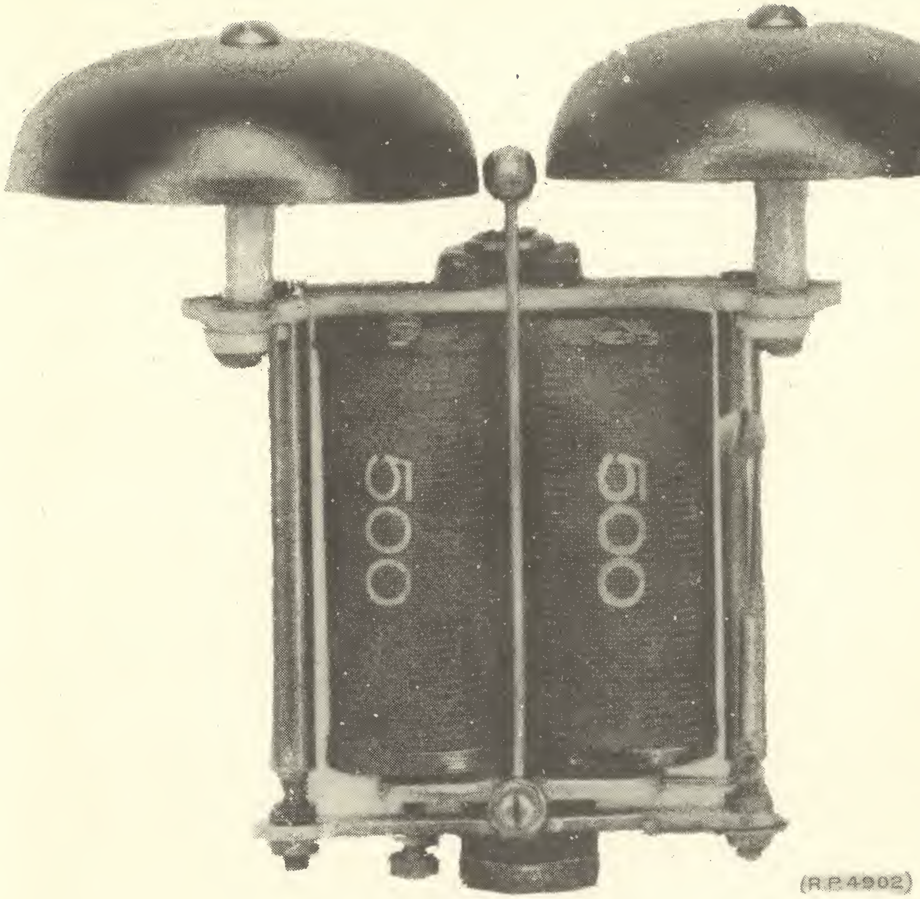


Fig. 22

CHAPTER II (continued)



RINGER

Fig. 23

electric current will strengthen the pole at the end of coil "L" and will either weaken the pole at the end of coil "R" or reverse its polarity, depending upon the strength of the energizing current. The armature will, therefore, be attracted by the pole of coil "L" and repelled by the pole of coil "R" with the result that the effect of the biasing spring will be overcome and the bell clapper will move to the opposite side and strike the "r" gong. When the impulse of current has stopped flowing, the magnetic relations in the ringer will be reestablished as they were before the current flowed, and the biasing spring will pull the armature back to its original position thereby causing the clapper to strike gong "l". Thus, a series of these impulses will continue to ring the bell if they occur in rapid succession. In actual practice a subscriber's bell is rung by means of alternating current sent out from the central office. As the alternating current flows first in one direction and then in the other, one of the impulses will be in the proper direction to produce the action of the bell which we have just described. The other half of the alternating current wave will produce a magnetic effect in such a way that the "R" pole becomes a strong south pole and the "L" pole changes to a

north pole, thereby helping the biasing spring to hold the armature stationary. In this way we see that one half of the alternating current wave pulls the armature over while the other one aids the biasing spring in pulling it back again.

In Fig. 23 is a picture of the ordinary ringer in which the more important elements have been clearly marked. This completes the description of the ordinary single party common battery subscriber's telephone.

CHAPTER III - LINE AND CORD CIRCUIT

We have considered means for transmitting speech by means of an electric current and are now ready to take up the various arrangements employed for interconnecting any two subscribers who may desire to carry on conversation.

On account of the large number of subscribers whom it is necessary to accommodate, means employed for switching are considerably more complicated and intricate than the apparatus necessary for transmission of speech itself. Before we take up a discussion of the switching circuit, however, it is advisable to give some consideration to the various pieces of apparatus employed in setting up connections. The most important of all these is the relay. A relay is essentially nothing more or less than an electrically operated switch by means of which a circuit may be opened or closed by the magnetic action of an electromagnet on the armature of the relay.

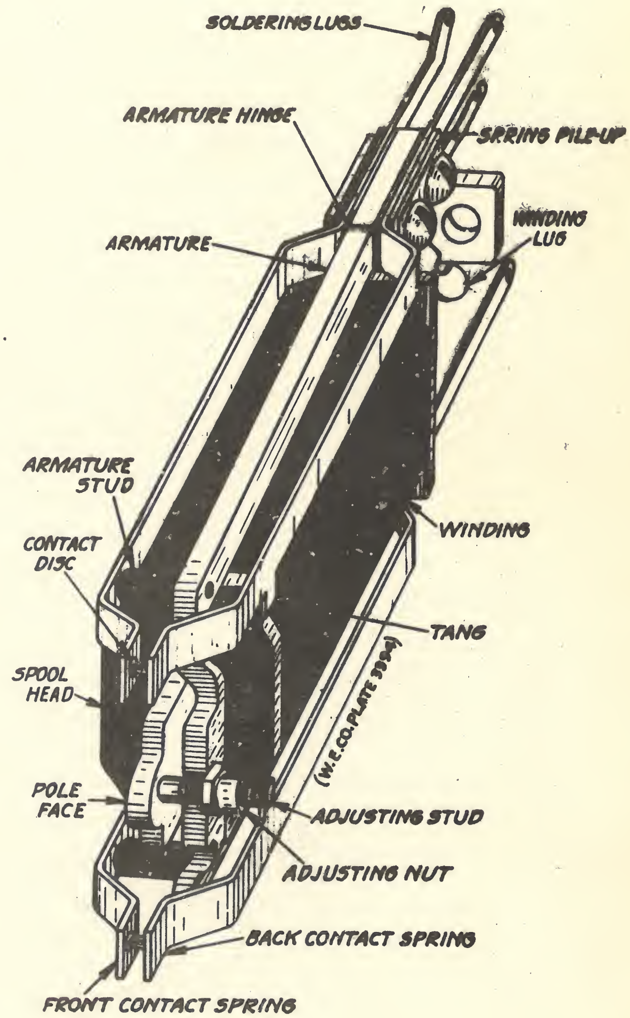


Fig. 24

In Fig. 24 is shown a typical relay. The action of this relay is exactly the same as that of the telegraph sounder although this may not be clear due to the peculiar construction of the relay. The armature consists of a "U" shaped piece hinged at the rear, the arrangement of which is more clearly shown in Fig. 25. When a current of electricity flows through the coil the core becomes an electro-magnet and pulls the armature over against the pole face. The arrows are intended to represent the magnetic force. The springs

of the relay to which are attached the contacts are also fastened at the rear. Two of the springs on one side rest against the spool head while the other two rest against insulating studs fastened to the armature. The top and bottom pairs of springs normally make contact at the contact points, the springs being so adjusted that when the contacts are made the armature is held away from the pole face of the electro-magnet.

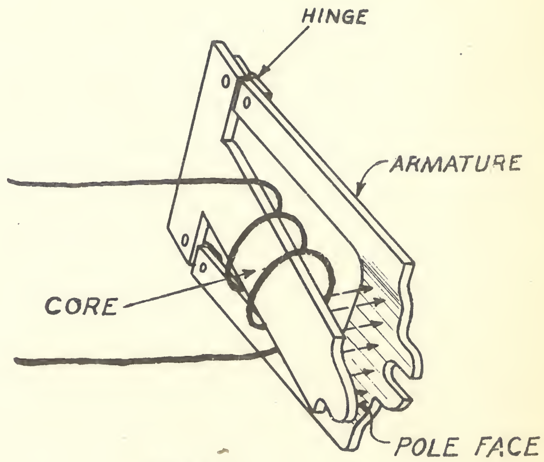


Fig. 25

When the armature is pulled against the pole face, the insulating studs push one of each of the two pairs of springs opening both sets of contacts. In actual practice relays are made up with a large variety of arrangements of springs and contacts, a typical relay having a greater combination of springs being shown in Fig. 26.

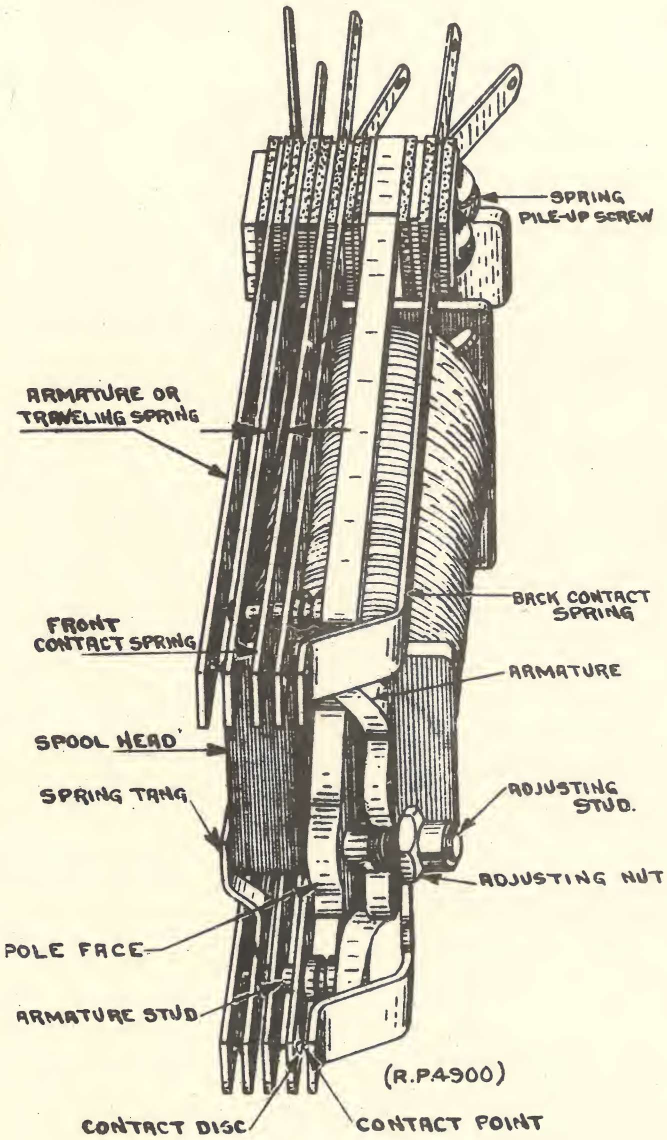


Fig. 26

We are now ready to consider some simpler pieces of apparatus which are involved in setting up connections between two subscribers. In Fig. 27 is shown an ordinary plug and jack. These two pieces of apparatus when taken together provide a convenient means for connecting two circuits together manually. Provision is made for connecting three conductors which, in telephone language, are known as the "tip, ring and sleeve", being named for the parts of the plug to which they are connected, the tip wire being connected to the tip of the plug, the ring to the ring of the plug and the sleeve to the sleeve of the plug as shown in the figure. The parts of the jack with which the plug makes contact bear the corres-

ponding designations. In considering our transmission circuits, only two wires were necessary and these are normally connected to the tip and ring. The third or sleeve wire is used for signalling purposes within the central office and does not extend to the subscriber's station.

There is also another form of switch which may be manually operated known as a "key" which is used very extensively in setting up telephone connections. A typical example is shown in Fig. 28. This particular key may be operated in either direction. The peculiar shape of the spring against which the roller operates when moved to the right is for the purpose of locking the key in the operated position when it has been pushed over in that direction. On the opposite side a straight spring is used so that when the key is operated in that direction it will immediately return to normal as soon as the handle of the key is released. It should be noted that keys may be used for opening contacts as well as closing contacts as is the case in this example.

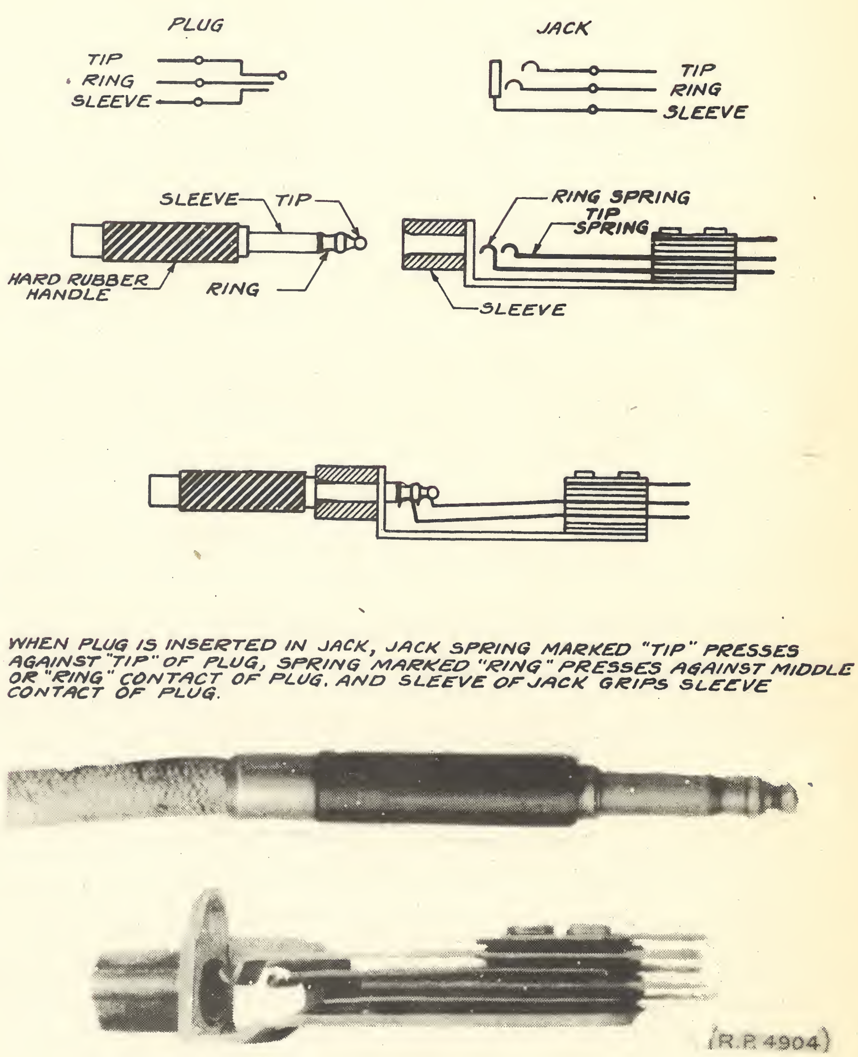


Fig. 27

We are now ready to consider what happens when the subscriber removes the receiver from the switchhook to call central. Under this condition a lamp is lighted in the face of the switchboard in front of an operator. The means by which this is accomplished is shown in the circuit in Fig. 29. A circuit is completed from one side of the battery to one winding of the relay, over one side of the line through one winding of the induction coil, transmitter, back over the line to the other winding of the relay to the battery. The relay is energized pulling up its armature closing the contact which lights the lamp by connecting it across the battery.

The operator, upon seeing the light, inserts the plug of a cord into the jack which is associated with the lighted lamp. After ascertaining what number is desired, she plugs the other end of the cord into a jack connected to the called subscriber's line, and operates a key which rings the bell in the called subscriber's telephone. For the sake of simplicity, the second plug and jack have been omitted. It should be noted that in the operation of the key the two inside contacts are broken, thus disconnecting the battery and repeating coil from the circuit and that the outside contacts connect alternating current directly to the subscriber's telephone. When the ringing key is released, the contacts return to normal as they are non-locking, thus again connecting the battery to the called subscriber's telephone in order to supply electric current through the transmitter to enable the subscribers to talk.

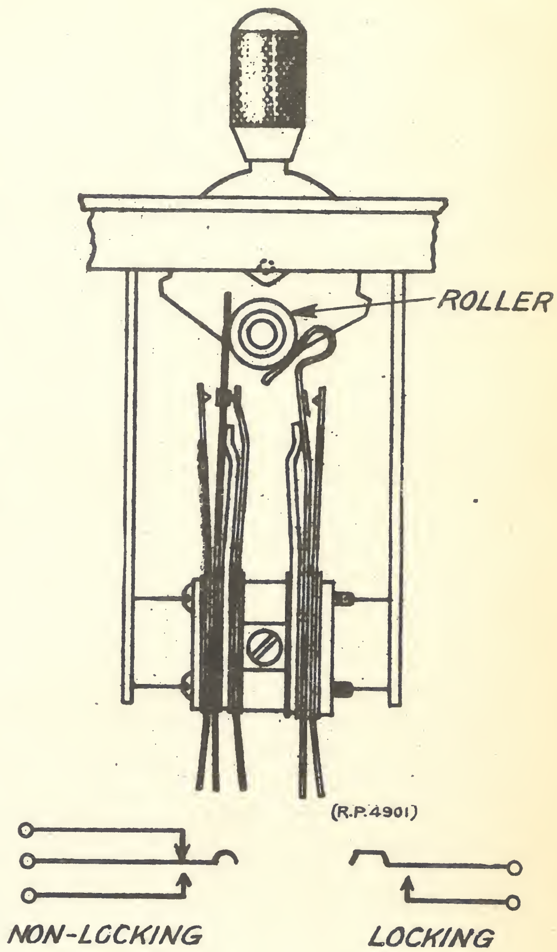


Fig. 28

As already stated, the plugs and jacks have three conductors instead of two. The use of the third conductor will now be described. Let us assume that the calling subscriber removes the receiver from the switchhook and that the relay marked "line relay" in Fig. 30 operates, lighting the "line lamp" as previously described. In this case the circuit for operating the line relay is through the contacts of the "cut-off"relay; otherwise it is exactly the same.

The operator, upon seeing the lighted line lamp, inserts the plug of a cord into the corresponding jack, known as an "answering" jack, as she is answering a call. We now have a circuit

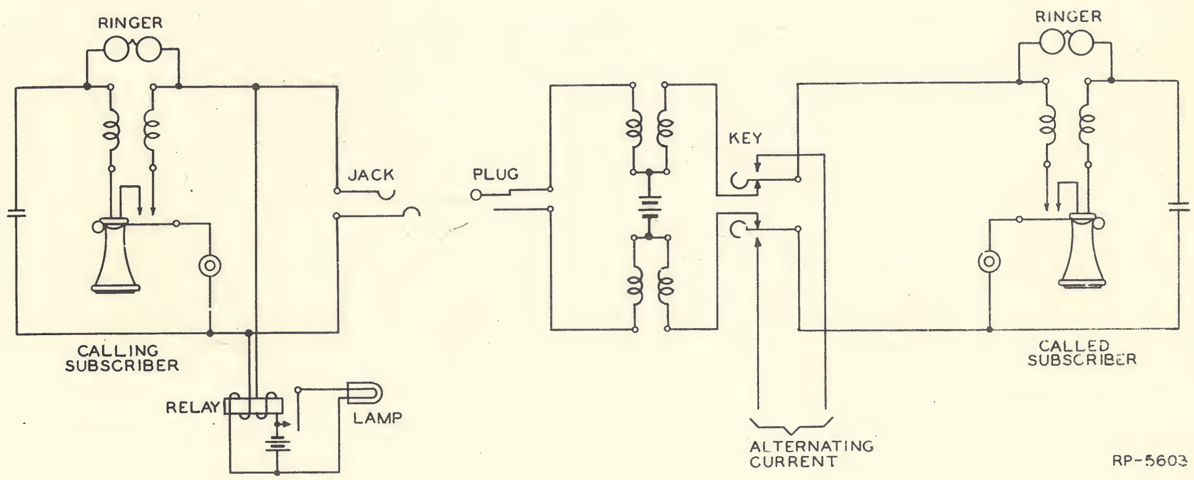


Fig. 29

CHAPTER III (continued)

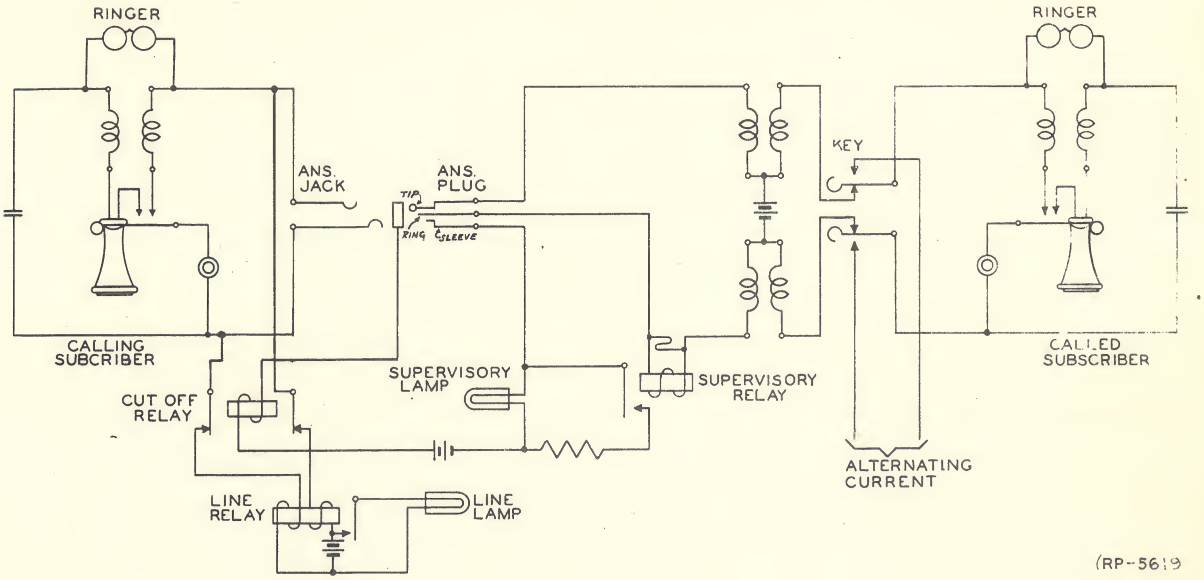


Fig. 30

from one side of the battery to the winding of the cut-off relay, to the sleeve of the answering jack, sleeve of the answering plug, supervisory lamp of the cord circuit, back to battery. This operates the cut-off relay which, as the name implies, "cuts off" the line relay from across the line. This operation of the cut-off relay opens the circuit of the line relay which releases its armature, extinguishing the line lamp. Under this condition the supervisory lamp in the cord circuit would be lighted if it were not for the operation of the supervisory relay in the cord circuit which operates over a path from battery, one winding of the repeating coil, winding of the supervisory relay, ring of plug, ring of jack, one side of line to transmitter in the subscriber's telephone, one winding of induction coil, back over the line, tip of jack, tip of plug, one winding of repeating coil, to battery.

The operation of this relay places a resistance across the supervisory lamp. This resistance allows enough of the current to flow through this auxiliary path to dim the lamp so that it is not visible to the operator. The completion of the connection to the called subscriber is the same as previously described.

We are now ready to consider a more complete connection such as that shown in Fig. 31. This circuit is the same as that already shown except that the plug and jacks for the called subscriber have been shown and also that multiple jacks as well as answering jacks have been introduced. In order that any operator may complete a connection to any subscriber, it is necessary for her to have access to any subscriber's line. It is, therefore, necessary to extend the subscribers' lines throughout the switchboard so that every subscriber's line will be within reach of every operator. This is done by means of the multiple jacks which are used exclusively for completing connections to called subscribers. These multiple jacks are exactly the same as answering jacks except that they have no lamp equipment associated with them. The answering jacks usually appear only once in the switchboard and have lamps associated with them, whereas the multiple jacks appear

CHAPTER III (continued)

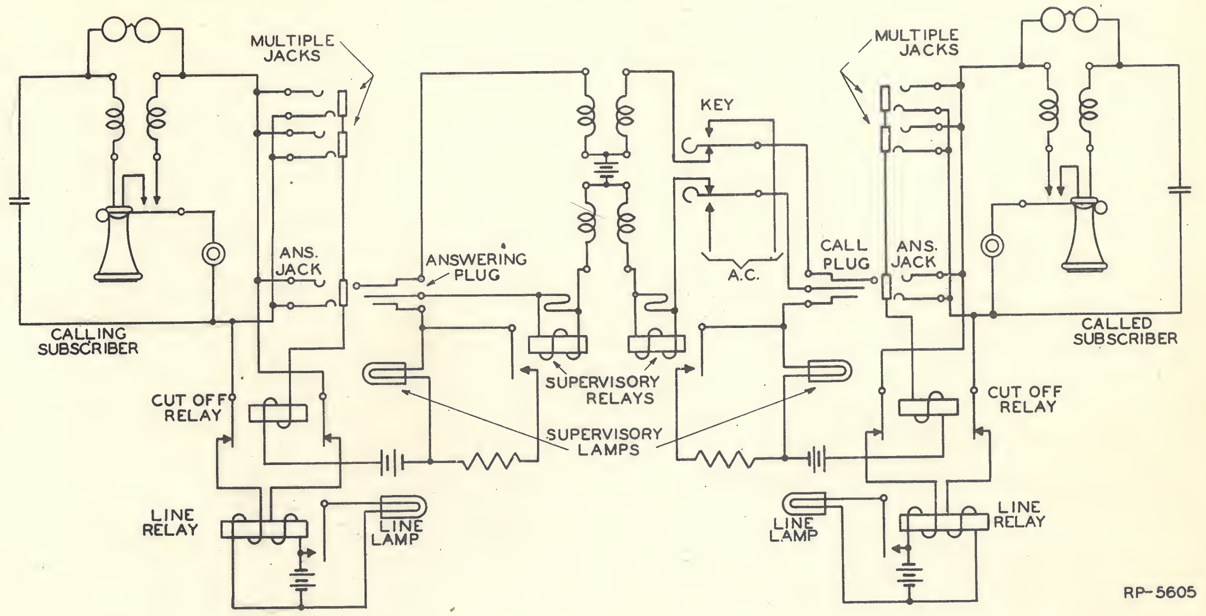


Fig. 31

throughout the switchboard within convenient reach of all operators but have no lamps. Thus, an incoming call always appears in the same point in the switchboard whereas calls may be completed to any subscriber from any position throughout the switchboard.

It should be noted that the sleeves of the answering and multiple jacks are connected together. This is for the purpose of operating the cut-off relay of the called subscriber's line in order to clear the line of the line relay while conversation is being carried on.

We are now ready to consider the means by which the operator is able to carry on conversation with the subscriber to ascertain what number the subscriber is calling. A simplified arrangement to illustrate this is shown in Fig. 32.

When a subscriber originates a call and the operator has plugged into the answering jack, she operates a listening key associated with the cord. This connects the operator's telephone set across the cord circuit. From the convention it will be noted that the listening key is of the locking type whereas the ringing key is non-locking.

The operation of the telephone circuit from a transmission standpoint is as follows: battery is supplied to the transmitter through what is known as a retardation coil, one winding of the induction coil, back to battery. This retardation coil is inserted for the purpose of preventing the alternating current from flowing through the battery and has the effect of choking back or retarding the alternating current. This is necessary in order to prevent cross-talk with other operators' sets or subscribers.

A condenser is provided which, as we have already learned, will allow the

CHAPTER III (continued)

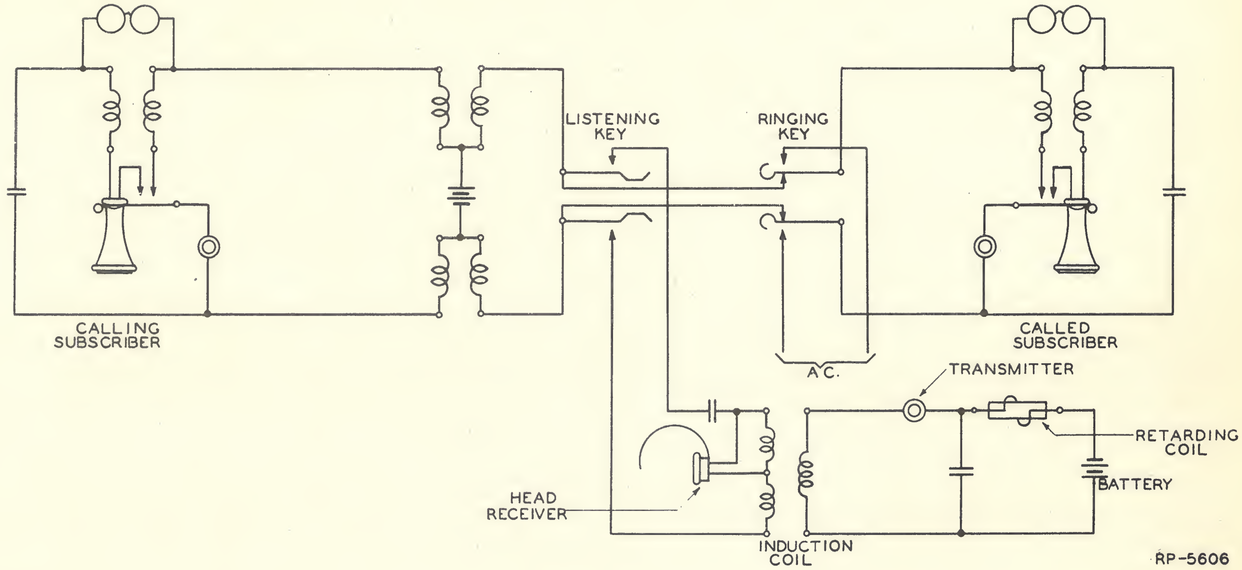


Fig. 32

alternating current to circulate in a path through the transmitter and the winding of the induction coil. A condenser is inserted in series with the other winding of the induction coil and receiver in order to prevent the central office battery from flowing through this circuit when the listening key is operated. This does not, of course, interfere with the alternating voice currents from flowing in this circuit.

The purpose of the supervisory lamps used in a subscriber's cord circuit is to indicate whether or not the subscriber's receiver is on the hook, and denotes to the operator that the subscriber has completed his conversation and hung up the receiver. When both supervisory lamps have lighted, the operator removes the cords from the jacks. The supervisory lamp lights when the receiver is placed upon the switchhook due to the fact that the circuit is open at the contacts of the switchhook, allowing the supervisory relay to release which removes the resistance shunt from around the lamp, thus allowing it to burn brightly.

CHAPTER IV - THE INTEROFFICE CALL

A single central office can accommodate only a limited number of subscribers, the largest offices being designed to take care of 10,500 lines. In a large city there are thousands of subscribers and it is necessary to provide a number of central offices with facilities for interconnecting each office in order that subscribers of one central office may talk with subscribers of another central office. This necessitates trunking the calls from one office to the other over cable pairs used especially for this purpose.

It is the usual practice to terminate the subscribers' lines in a separate switchboard from the trunks, the board in which the subscribers' lines terminate being known as the subscribers' or "A" switchboard, and the board in which the trunks terminate being known as the trunk or "B" switchboard. In Fig. 33 is shown schematically the routing of a call from an "A" board to the "B" board, the "A" board being located in the originating and the "B" board in the terminating office.

In addition to the trunk circuits between offices, it is also necessary to provide call circuits to enable the operator at the "A" board to pass the call to the operator at the "B" board. The operations which take place in completing a call between two offices are briefly as follows:

The subscriber removes the receiver from the switchhook and the "A" operator answers the call. Upon receiving a request for a subscriber in another office, the "A" operator restores the listening key to normal, presses a call circuit key and talks directly to the trunk operator at the completing office, requesting the connection to the desired subscriber. The trunk operator in turn assigns an idle trunk which has the same number at the originating end as at the concluding end. The "A" operator inserts a calling cord into the outgoing trunk jack and the "B" operator completes the circuit by inserting the plug of the particular trunk assigned into the jack of the desired subscriber.

It should be understood that in order to complete calls in either direction between two offices, it is necessary that both offices have an "A" board and a "B" board. This is illustrated by the simple diagram in Fig. 34.

In view of the fact that it is necessary to trunk a majority of the calls in cities having a large number of central offices, it has been found more economical to dispense with the subscribers' multiple in the "A" switchboards entirely and trunk all calls to the "B" board. The operation is the same whether the call goes to a distant office or to the "B" board of the same office.

In Fig. 35 is shown the face of an "A" switchboard with the various groups of circuits clearly marked.

In Fig. 36 is shown the face of a "B" board with the subscribers' multiple shown above and the plugs of the trunks below on the key shelf.

Before we take up further the arrangement and layout of the apparatus in a central office, let us discuss one important operating feature which must be provided for. This is the "busy" test. We will consider first the case of an "A" operator

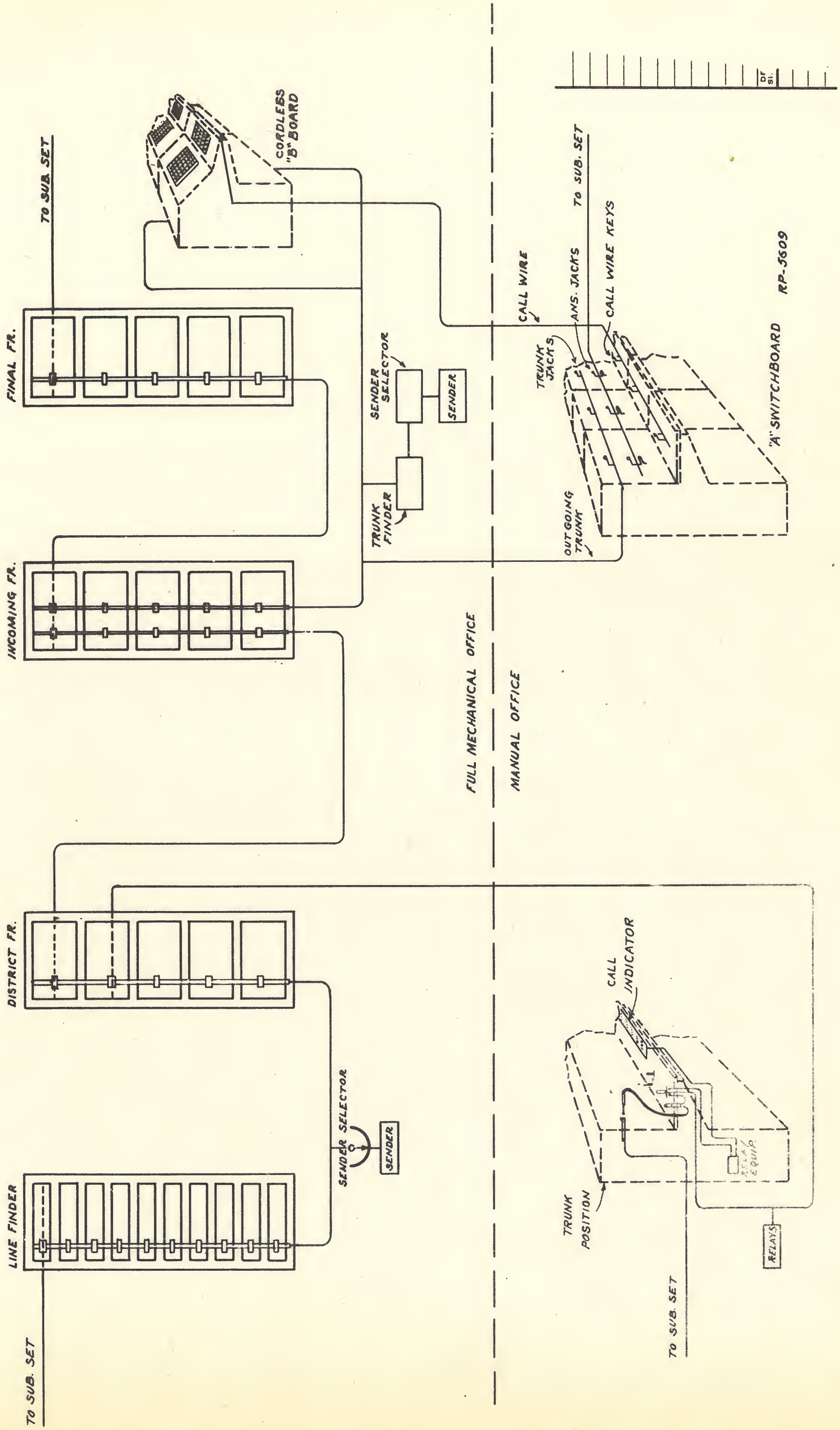

TO SUB. SET
LINE FINDER
SENDER SELECTOR
SENDER
DISTRICT FR.
INCOMING FR.
TRUNK FINDER
SENDER SELECTOR
SENDER
FINAL FR.
TO SUB. SET
CORDLESS "B" BOARD
FULL MECHANICAL OFFICE
MANUAL OFFICE
TRUNK POSITION
CALL INDICATOR
RELAYS
TO SUB. SET
OUT GOING TRUNK
TRUNK JACKS
CALL WIRE
ANS. JACKS
CALL WIRE KEYS
TO SUB. SET
"A" SWITCHBOARD
RP-3509

Fig. 33

completing a call with a subscriber's cord circuit, and let us suppose that the subscriber called is already busy, that is, there is already a cord circuit plugged into a multiple jack of the line at some other position. Before an operator inserts a cord into the jack of the called subscriber's line, she touches the tip of the cord to the sleeve of the jack. If the line is busy, a click will be heard in the receiver to indicate the busy condition. The circuit arrangement by which this is accomplished is shown in Fig. 37. Here one cord is indicated as being plugged into a multiple jack and the tip of another cord is indicated as touching the sleeve of another multiple jack of the same line. A circuit may be traced from battery through the supervisory lamp of the cord circuit already inserted in the multiple, resistance, sleeve of cord, sleeve of jack, through the multiple to ground through the cut-off relay in the answering jack circuit. This, as we have already discussed, "cuts off" the line relay from across the tip and ring of the line during conversation. We can also trace from the sleeve of the multiple a circuit to the sleeve of the other multiple jack shown in the figure. When the operator touches the tip of the cord to the sleeve of this jack, an electric current flows over the path already traced from the sleeve of the first cord through the contact of the sleeve relay, winding of an induction coil, to ground. The second winding of this coil is connected to the receiver, and the momentary flow of current in the first winding produces a current in the second which causes a click in the receiver.

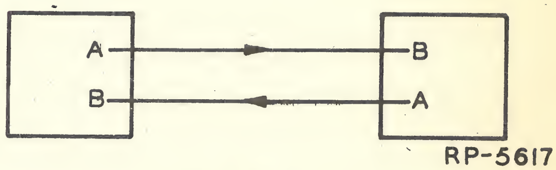


Fig. 34

It will be noted that the circuit arrangement of this cord is different from that shown in the simpler cord circuit which we had in a previous lesson. This subscriber's cord circuit is the one commonly used in central offices where all calls are trunked, that is, where 100% trunking is used, and has been shown here on account of its common use. The sleeve relay which controls the busy test operates when the cord is plugged into a multiple jack and transfers the tip of the cord from the busy test lead to the tip side of the cord circuit. A busy test circuit similar to this is used in trunk circuits and will therefore not be discussed here.

In case the "B" operator finds a subscriber's line busy, she plugs the cord of the trunk into a busy jack which places an interrupted tone on the trunk which the subscriber recognizes as a busy tone. It is necessary to use this arrangement as the "B" operator has no direct communication with the calling subscriber. In Fig. 36, showing the face of a "B" switchboard, a single strip of these busy jacks is shown just below the multiple.

The arrangement of the cabling between the various frames in a manual central office is shown in Fig. 38. The outside cables are brought into the central office and terminate at what is known as the main distributing frame, marked MDF on the diagram, both the subscriber's line and trunk cables being terminated at the same frames. In order to protect central office equipment from damage in case a subscriber's line or trunk circuit should come in contact with a building lighting circuit or a high voltage power line, the cables are terminated on protectors mounted on the MDF. From the protectors the lines or trunks are connected to the other side of the distributing frame by means of flexible wires known as "jumper" wires. The

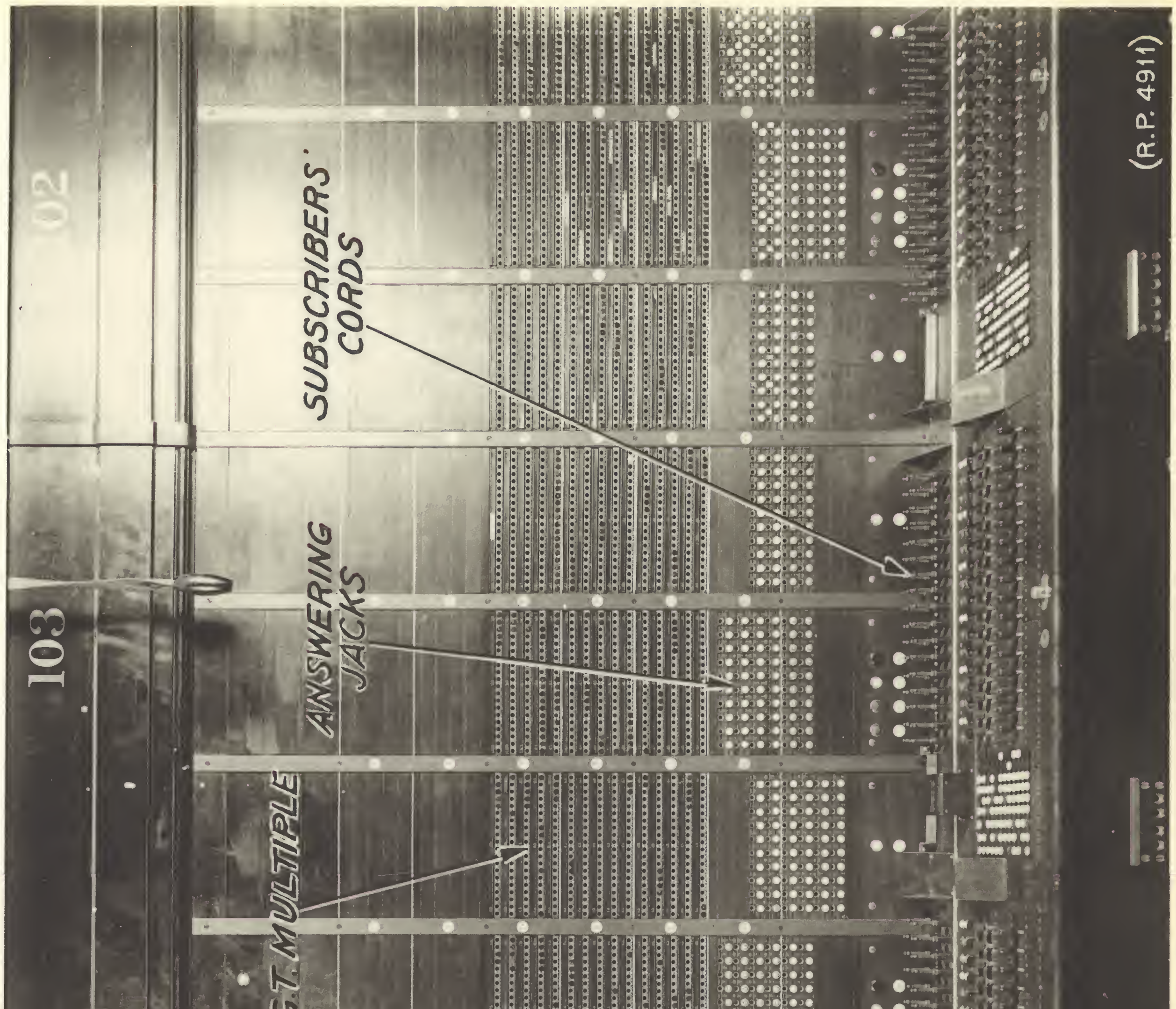

105
104
103
02
SUBSCRIBERS' CORDS
ANSWERING JACKS
O.G.T. MULTIPLE
CALL WIRE KEYS
(R.P. 4911)

Fig. 35

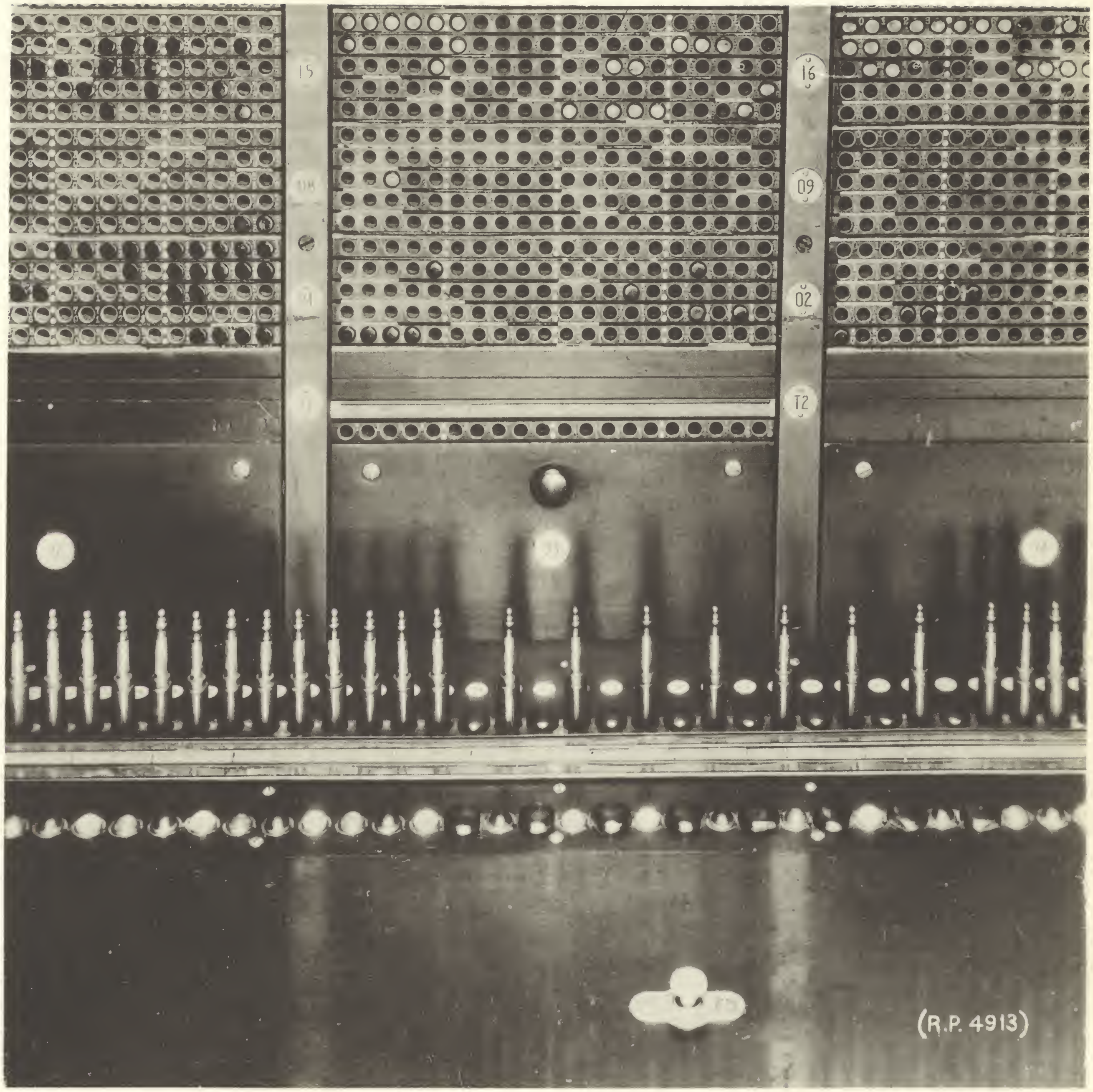


Fig. 36

path of a subscriber's line may be traced as follows: from the main distributing frame, cables are run to an intermediate distributing frame designated IDF. From the same terminal strips on which the cables from the main distributing frame terminate, cables are also run to the multiple in the "B" switchboard.

A cable is also shown to the subscribers' multiple in the "A" board but this multiple is used only in areas where 100% trunking is not economical. By means

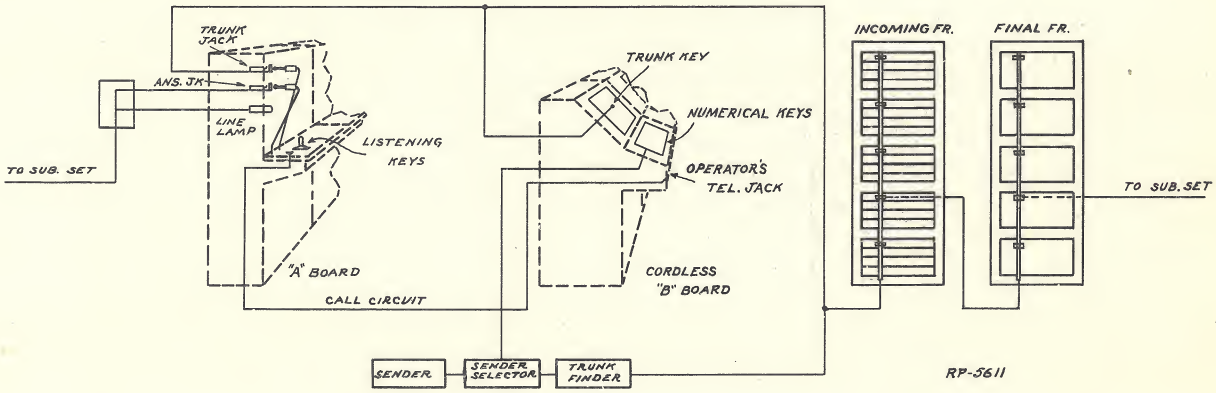

TRUNK
TRUNK JACK
ANS. JK
LINE LAMP
LISTENING KEYS
TO SUB. SET
"A" BOARD
CALL CIRCUIT
TRUNK KEY
NUMERICAL KEYS
OPERATOR'S TEL. JACK
CORDLESS "B" BOARD
INCOMING FR.
FINAL FR.
TO SUB. SET
SENDER
SENDER SELECTOR
TRUNK FINDER
RP-5611

Fig. 37

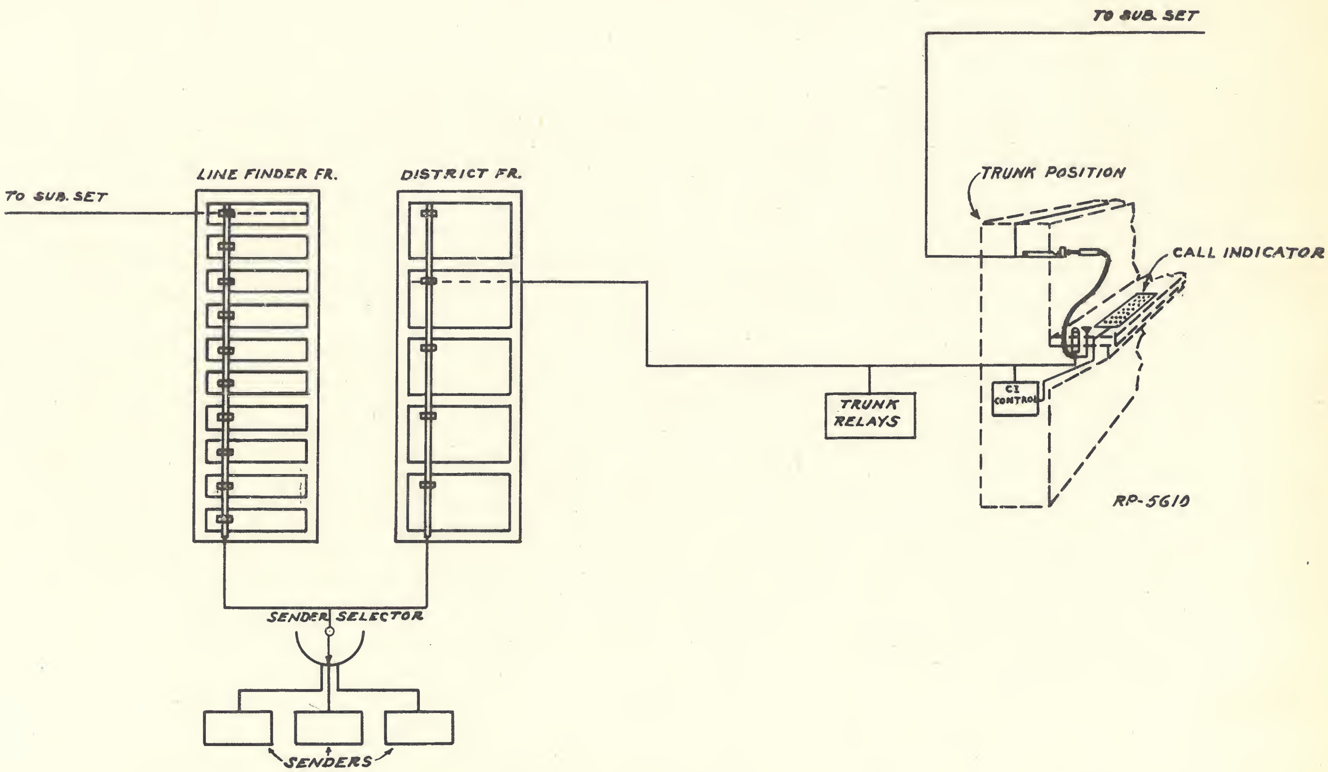
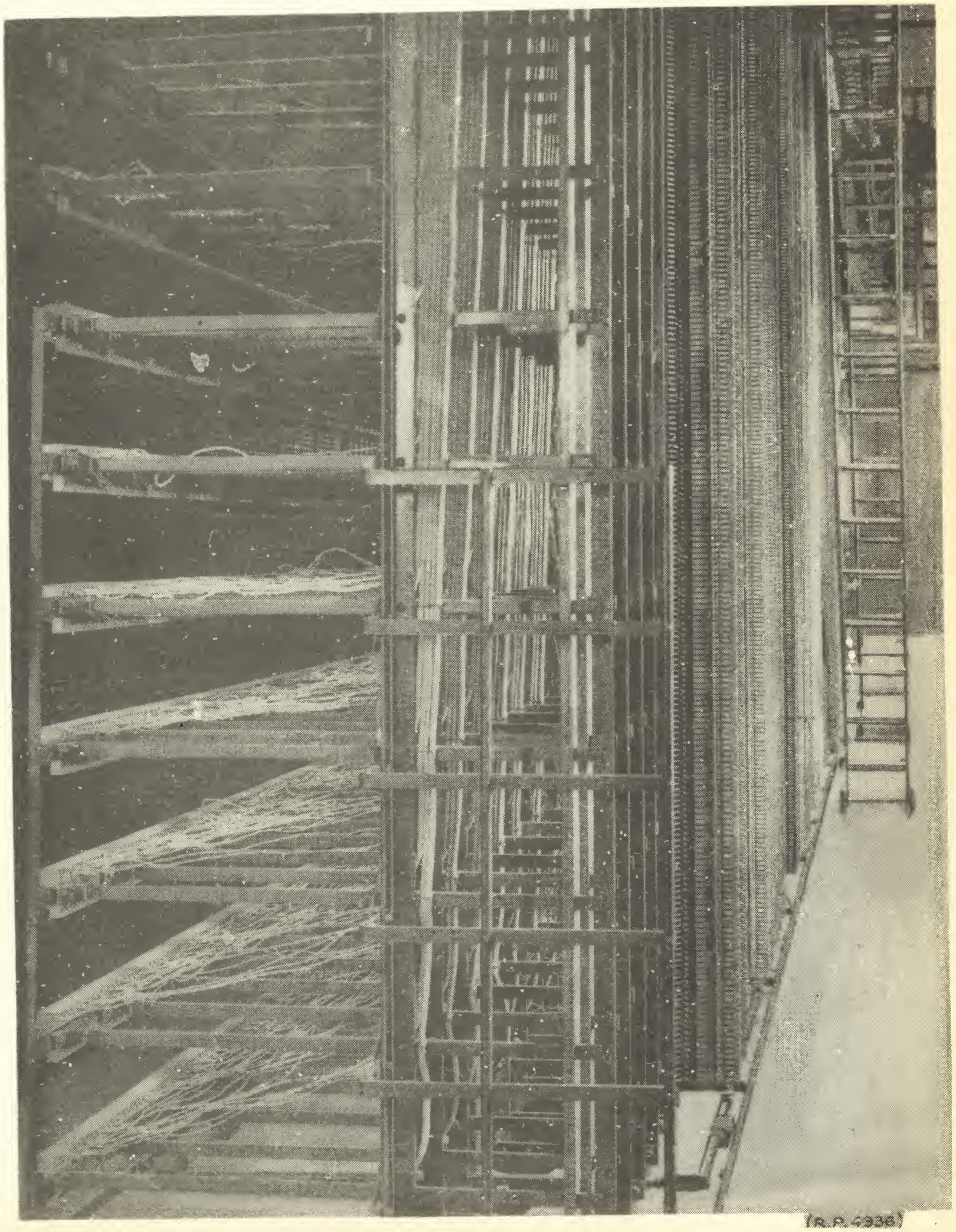

TO SUB. SET
TO SUB. SET
LINE FINDER FR.
DISTRICT FR.
TRUNK POSITION
CALL INDICATOR
CI CONTROL
TRUNK RELAYS
SENDER SELECTOR
SENDERS
RP-5610

Fig. 38

of jumper wire, the answering jack circuit, or the "line circuit" as it is called, is connected across the IDF to terminal strips on which are terminated cables to the answering jacks and lamps in the "A" switchboard and to the relay rack on which are located the line and cut-off relays of the answering jack circuits.

Incoming trunks from other offices terminate at protectors on the main distributing frame and are cross-connected to cables terminating at the trunk coil rack containing the repeating coils for the trunk circuits. From the repeating coils cables are run to the trunk relay rack and thence by cables to the trunk circuits in the "B" board. The outgoing trunk circuits from the "A" board are usually cabled directly to the main distributing frame except for a cable to the line relay rack on which are mounted resistances used in the sleeves of the outgoing trunks. The only cabling required for the subscribers' cord circuits is that to the coil rack where are mounted the repeating coils.

The main distributing frame is shown in Fig: 39. On one side are shown the protectors to which the outside



(R.P. 4936)

Fig. 39

CHAPTER IV (continued)

cables are connected, and on the other side the terminal strips on which the central office cables are terminated. A diagram of a protector is shown in Fig. 40. The two wires of the outside cable pair are connected to the terminals marked "cable" and the jumper to the terminals marked "jumper".

The circuit is completed from the cable terminals to the jumper terminals through the heat coils placed between the springs. These heat coils are so constructed that when a subscriber's line comes in contact with a high voltage power line, a soldered joint inside the coil will melt due to the heat produced by the excessive electric current and cause the heat coil to operate as shown on the right hand side in the figure. This presses a spring against the framework of the protector which is grounded, thus causing the current to be carried to ground instead of through the central office equipment. The construction of the heat coil is shown in Fig. 41. The high current flowing through the heat coil winding melts the solder holding the copper sleeve to the heat coil pin and the pressure of the protector spring on the head of the coil pushes the winding and sleeve along the pin which, in turn, pushes the spring against the grounded framework.

In addition to protecting the equipment against power circuits, the protector is also designed to provide protection against lightning. This is accomplished by providing two pieces of carbon between which is inserted a piece of mica, as shown in Fig. 40. The lightning discharge will jump the very small gap between the two carbon blocks and follow the framework of the protectors to ground.

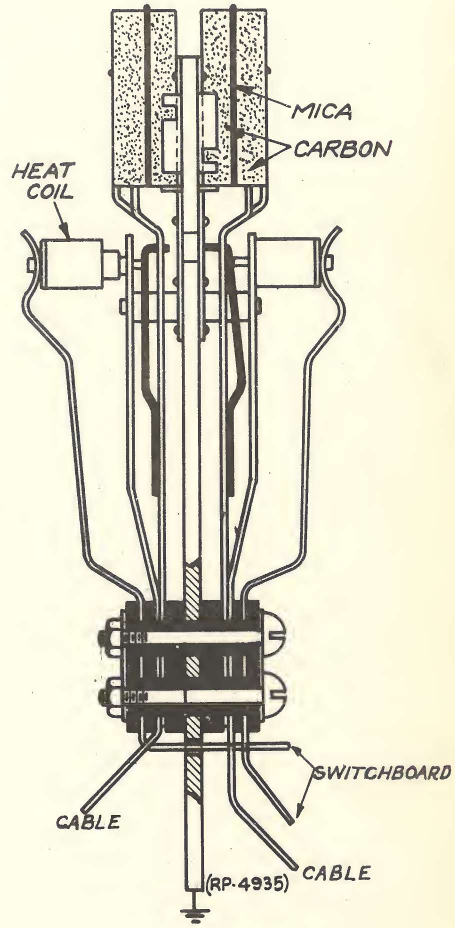


Fig. 40

In Fig. 42 is shown a picture of an intermediate distributing frame. This frame does not have protectors as the protection is always placed at the main distributing frame where the cables enter the office, thus affording the maximum amount of protection to the central office equipment. The main purpose of this frame is to provide a flexible means for connecting the multiple and answering jacks by means of jumpers. By this arrangement any answering jack can be connected to any multiple. It has been found more convenient in running the jumpers to have the terminal strips on one side of the frame arranged in horizontal rows and those on the other side of the frame arranged in vertical rows. This has led to the practice of designating one side of the frame as the horizontal side and the other as the vertical side and are usually designated HIDF and VIDF.

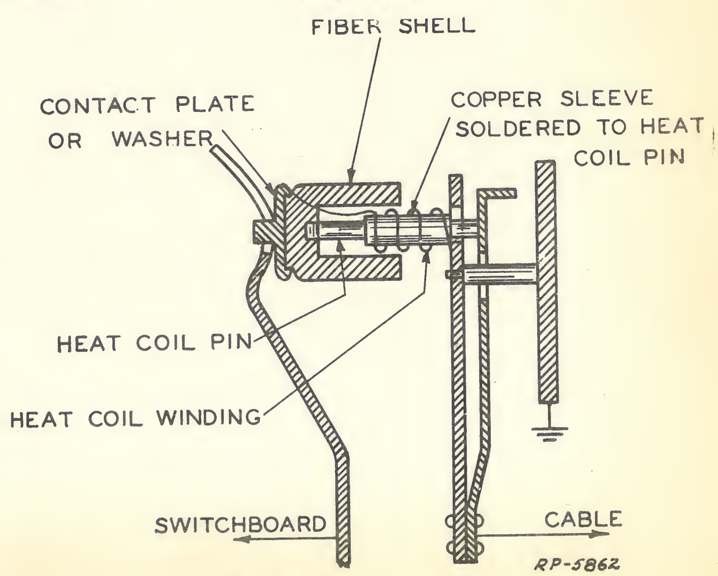


Fig. 41

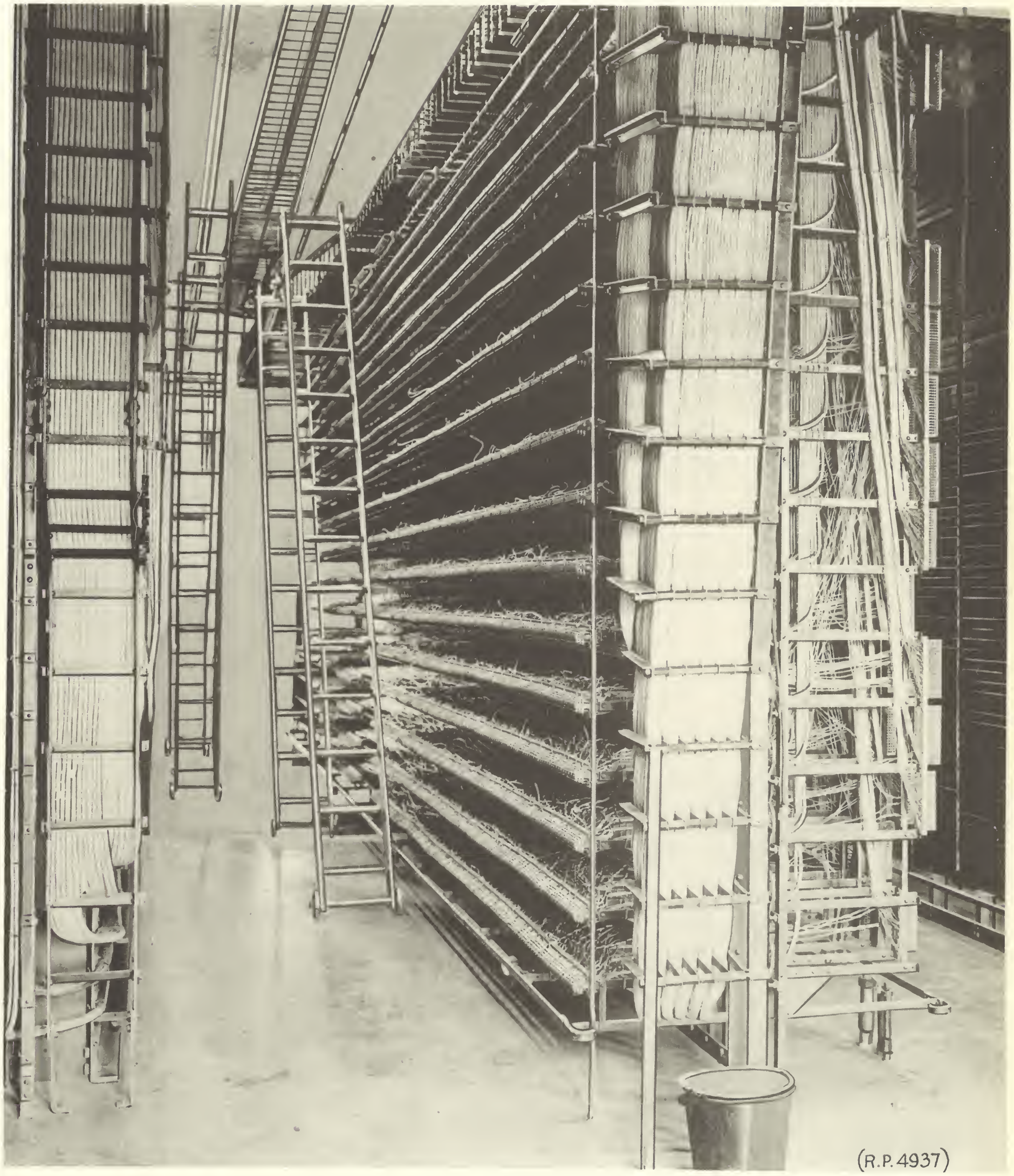


Fig. 42

CHAPTER IV (continued)

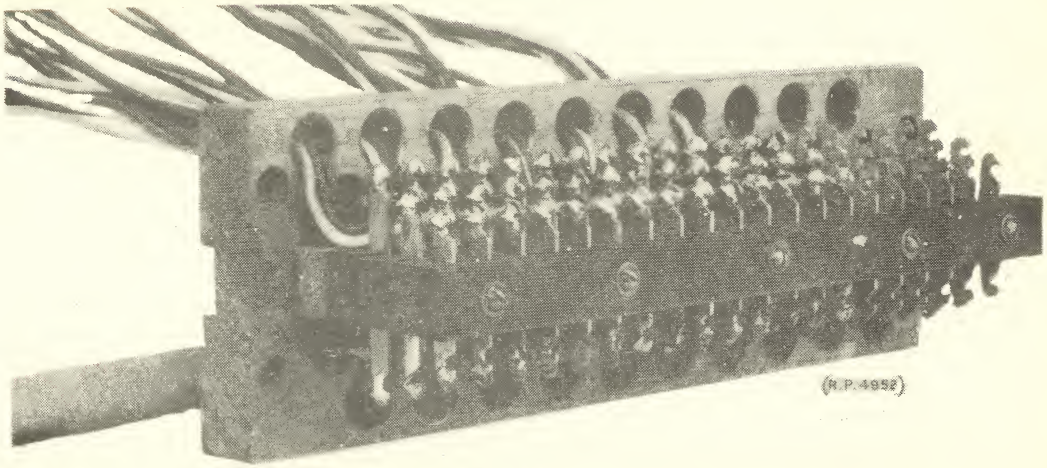


Fig 43

In Fig. 43 is shown a typical terminal strip used on the HIDF. The cable is connected to the bottom of the strip and the jumper wire to the top. The terminals are merely short metal pieces clamped between strips of fibre.

In Fig. 44 is shown the rear of a line relay rack on which are located the line and cut-off relays of the answering jack circuits.

In Fig. 45 is shown the front of a trunk relay rack on which are located the relays of the trunk circuits.

In Fig. 46 is shown the rear of an "A" board, with the outgoing trunk multiple, answering jacks, cord circuit relays, and operator's telephone circuit clearly marked. The rear of a "B" board has not been shown as there is very little equipment in one of these boards, most of the apparatus for the trunk circuits being located in the terminal room on frames and racks.

In Fig. 47 are shown a coil rack and fuse panel. The coils are placed on horizontal shelves and the cables connected to them supported on the shelves in front of the coils. A fuse is provided in each circuit to protect the apparatus and circuits from damage from excessive current. These fuses are mounted on a panel which is usually located adjacent to the coil rack as this makes the most convenient cabling arrangement.

In order that a central office maintenance man may know when a fuse has blown, an alarm is provided. For this purpose a special fuse, commonly called a "grasshopper" fuse, shown in Fig. 48, is generally used. The fuse wire is attached at one end to a small coil spring and at the other end to a leaf spring, as shown in the figure. When the fuse blows, the action that takes place is shown in Fig. 49. The leaf spring underneath presses against an alarm bar closing the circuit from the battery bar to an alarm circuit which immediately starts the alarm, notifying the maintenance man by the ringing of a bell that a fuse has blown.

Lamps located on the fuse panel in line with each strip of fuses indicate the strip in which the blown fuse is located. To facilitate the location of the particular fuse in the strip, a glass bead is placed on the end of the coil spring, which, when released by the blowing of the fuse, projects out beyond the line of the other fuses in such a way as to be readily located.

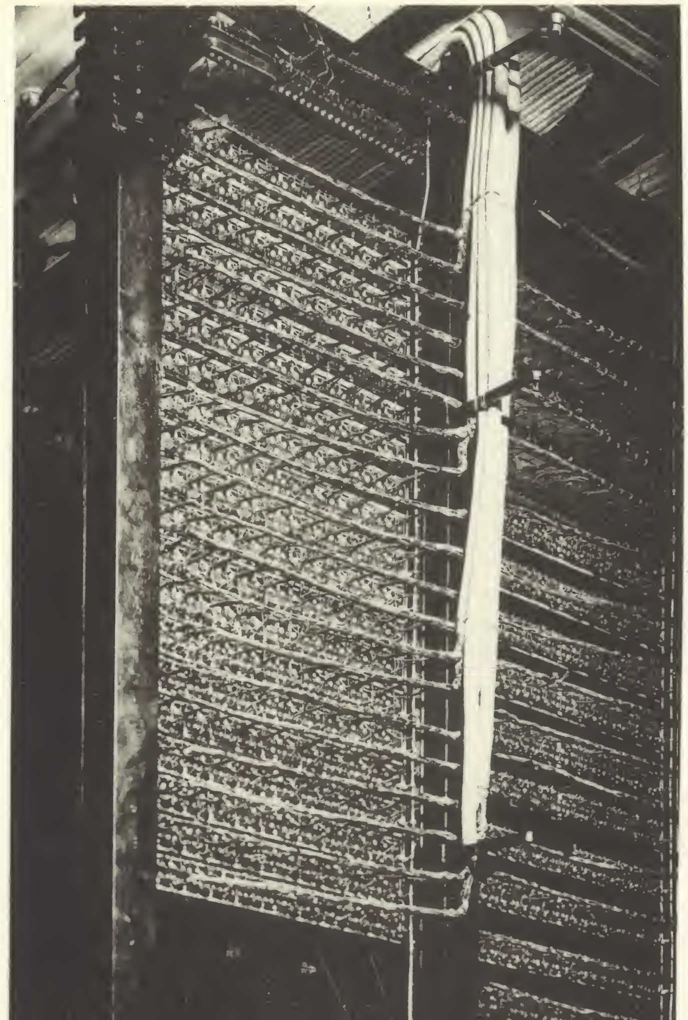


Fig. 44

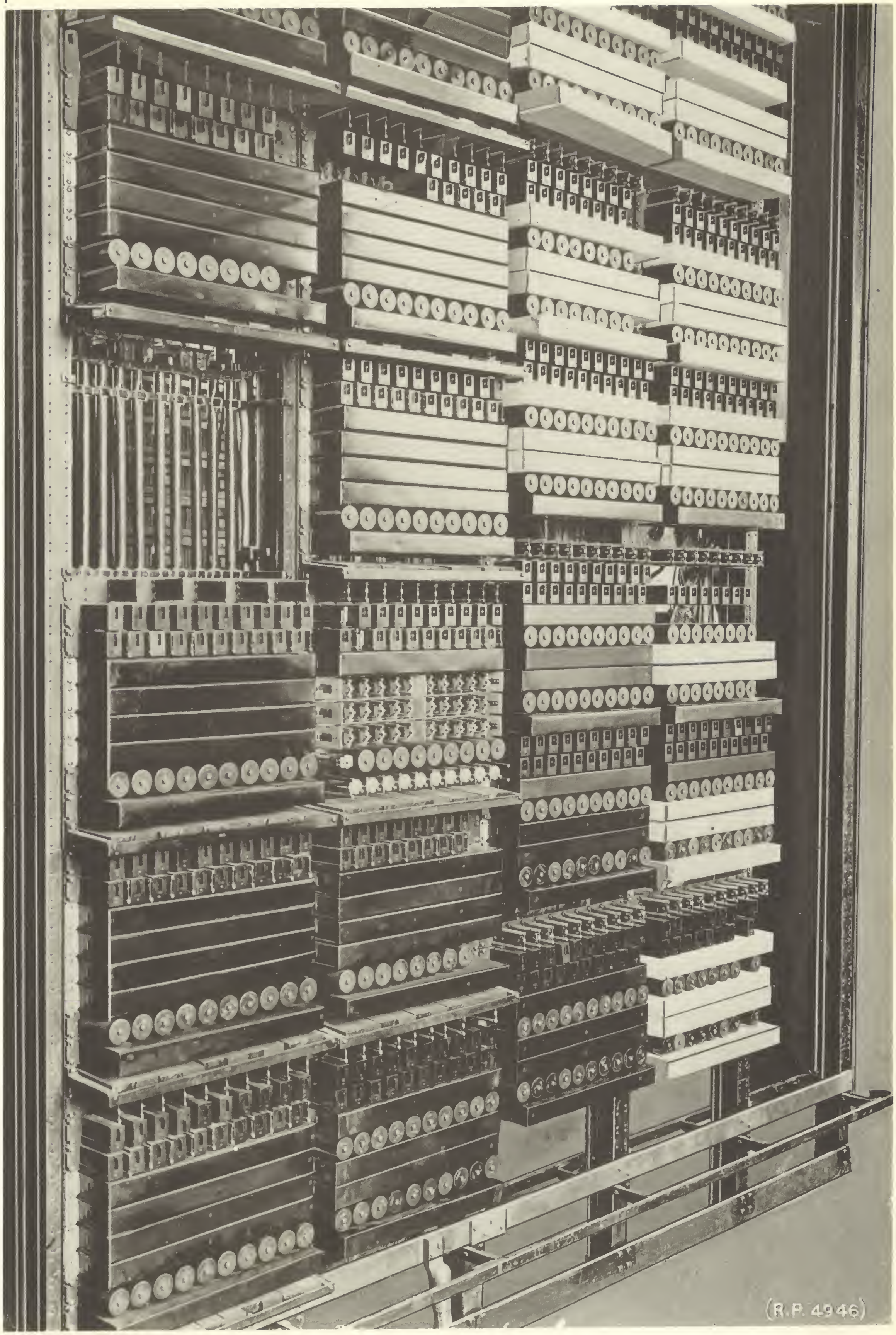


Fig. 45

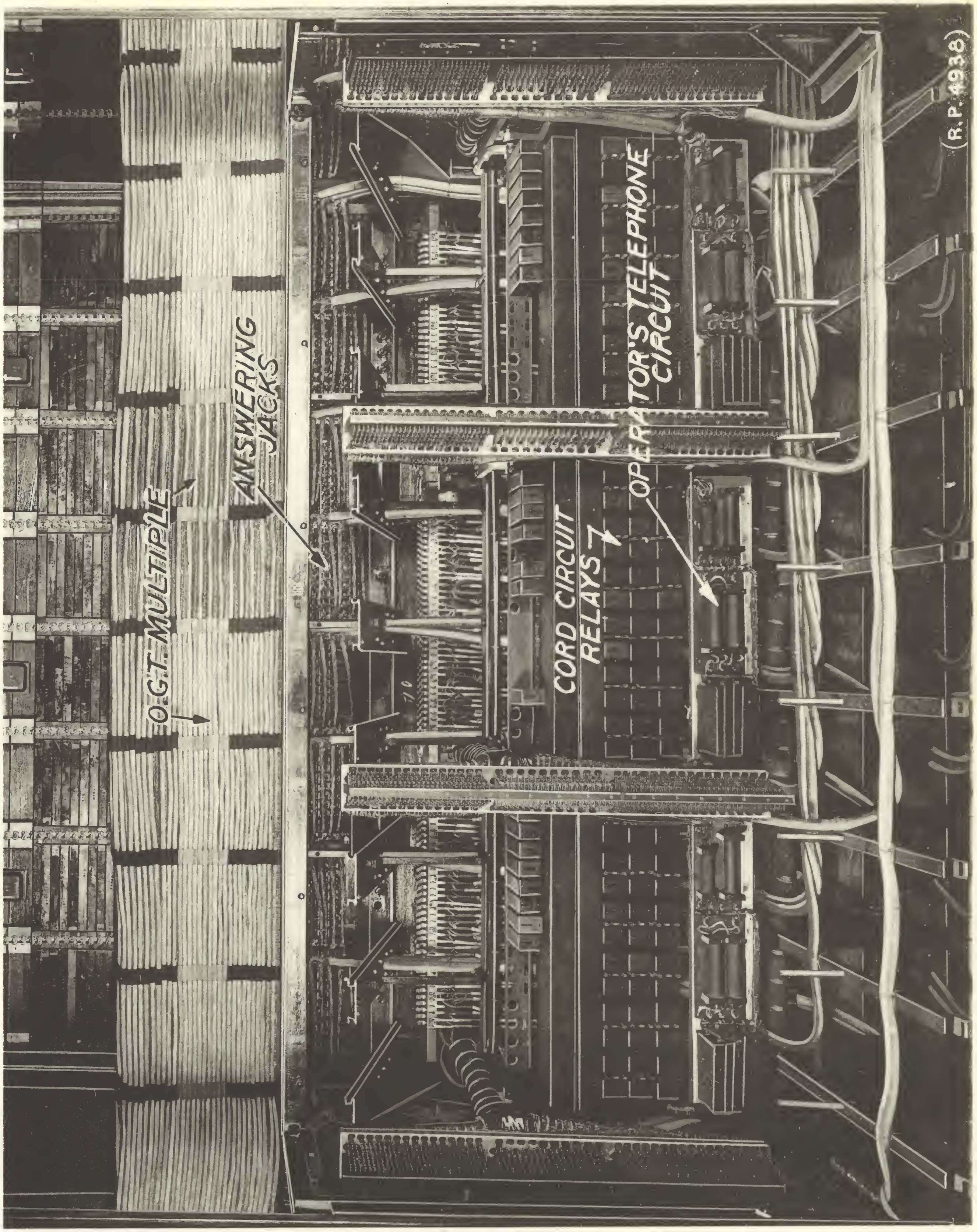
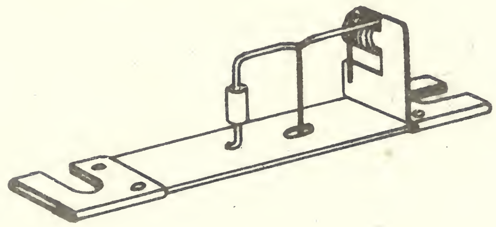

O.G.T. MULTIPLE
ANSWERING JACKS
CORD CIRCUIT RELAYS
OPERATOR'S TELEPHONE CIRCUIT
(R.P. 4938)

Fig. 46

Fig. 47



(RP-4917)

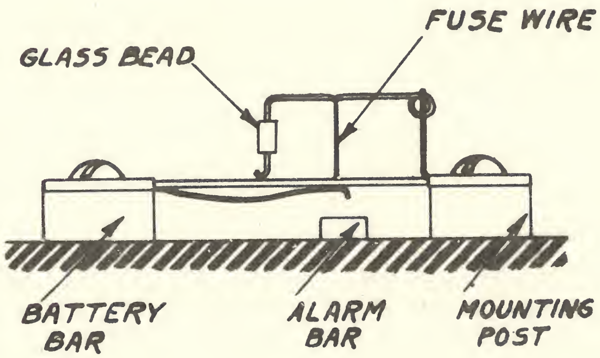


Fig. 48

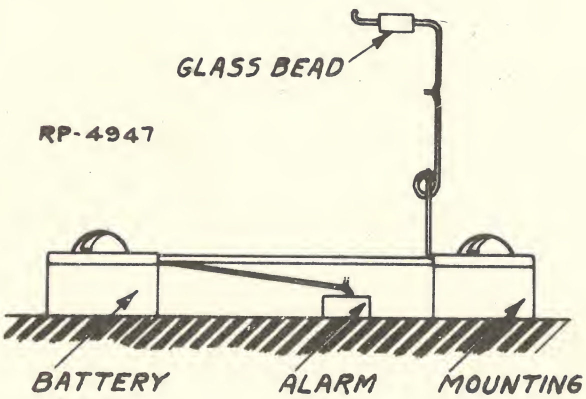


Fig. 49

CHAPTER V - PANEL MACHINE SWITCHING EQUIPMENT

The panel machine switching system is a system for completing telephone connections automatically in response to dial pulses originated by the subscriber. The dial which is illustrated in Fig. 50 is located at the subscriber's station. In the case of a desk stand, it is mounted on the base, and in the case of a wall set, on the face of the set itself. It is so designed that by manipulating a finger wheel electrical impulses are sent out over the line corresponding with the numbers or letters appearing in the holes. When used in the larger cities, the design bears certain letters of the alphabet in addition to the numbers. The letters are used for dialing the first three letters of the office name.

The circuit of a subscriber's set with a dial is shown in Fig. 51. Spring "A" opens the circuit to the receiver and closes a path around the transmitter, and is so arranged that it remains closed during the time that each series of impulses is being sent. Spring "B" is the pulsing spring which opens and closes as the dial returns to normal, producing the actual pulses. The pulsing circuit may be traced from the ring side of the line through one winding of the induction coil, contacts of switchhook, spring "A" of dial, spring "B" of dial, back on the tip side of the line.

In Fig. 52 is shown a typical selector frame with the various pieces of apparatus designated. There are 5 panel type multiple banks and 60 selector circuits on a frame, 30 selectors on each side.

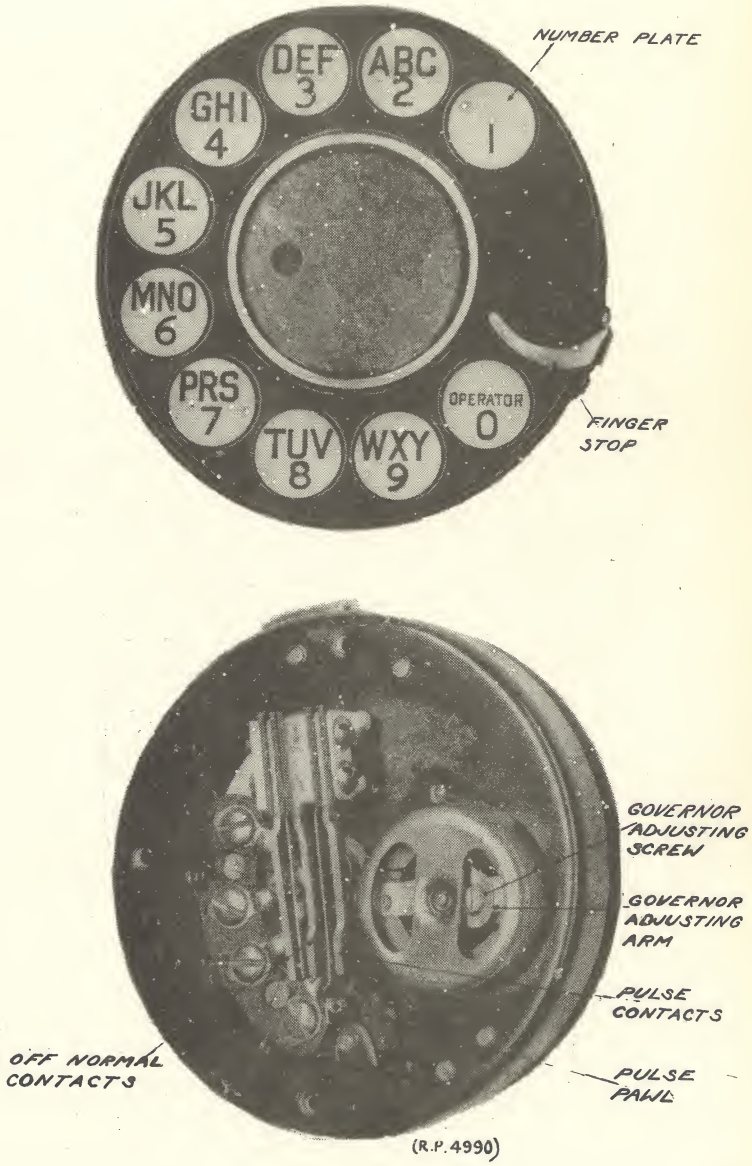


Fig. 50

CHAPTER V

A multiple bank is shown in Fig. 53. This consists of flat punchings about $3\frac{1}{2}$ feet long and 1 inch wide overall. Each of these strips has lugs on each side with which the selectors can make contact. In this particular bank 300 of these strips are piled one above the other, separated by insulation and securely bolted together, forming a panel about 15 inches high. This bank provides a multiple consisting of tip, ring and sleeve connection for 100 lines, appearing 60 times, that is, 30 on each side. It is this panel which has given the name to the system.

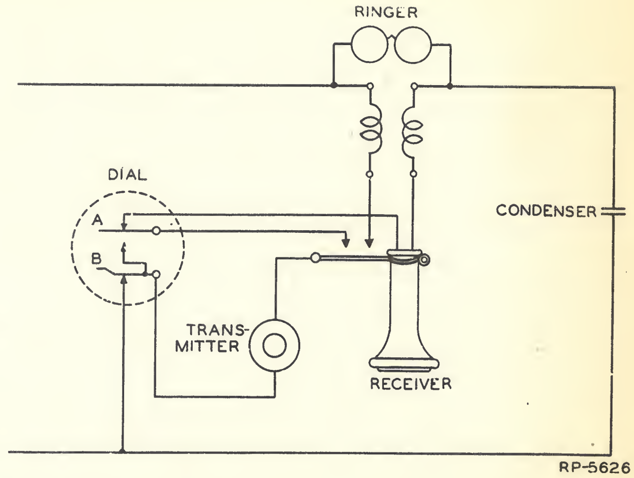


Fig. 51

In Fig. 54 a section of the multiple bank is shown in more detail with the selector brushes making contact with the lugs or terminals. The selectors are moved up and down by means of a friction clutch and continuously rotating cork rolls at the bottom of the frame. A picture of the partially assembled frame showing the multiple banks and the cork roll is shown in Fig. 55, and the cork roll alone is shown in Fig. 56. There are two rolls on each side which rotate in opposite direction, one of them being used to move the selector up and the other one to move it down. The friction clutch used for controlling the movement of the selector is shown in Fig. 57. The operation of the clutch can be best understood from the diagram in Fig. 58. When the up-drive magnet is energized, the roller on the lower roller arm presses the rack against the cork roll which cuases the rack to which the selector rod is attached to move upward as long as the magnet is energized.

The rack as shown in the picture in Fig. 57 is notched and a pawl, also shown in this figure, holds the rack by these notches at whatever point it is stopped. To restore a selector rod to normal, the down-drive magnet is energized and the roller on the down-drive roller arm presses the rack against the other cork roll which pulls the selector down.

In Fig. 59 is shown the assembly of the selector to the rack. As shown in Fig. 60, the selector consists of a metal tube supported in bearings, allowing vertical motion and carrying 5 sets of brushes. Each one of the 5 sets of brushes is arranged to make connection to the tip, ring and sleeve terminals of the panel banks before which it normally stands, and the tip, ring and sleeve contact members of all 5 of these brushes are multipled together. They are normally free from contact with the terminals but any set may be tripped mechanically, so that that set will contact successively over terminals as the selector rises.

A magnet is provided in the clutch for tripping,by means of a rotating rod or trip rod, any one of the 5 sets of brushes into mechanical engagement with the terminals. In choosing a trunk or line, that one of the 5 sets of brushes which has access to the panel in which the desired trunk or line appears is tripped so that it makes contact with the bank terminals before it. The selector then moves upward under the proper control until the tripped brush engages the desired line or trunk. The selector is then held in this position by the pawl in the clutch. When the connection is to be taken down, the pawl is withdrawn and the selector is carried back to normal under control of the clutch. When the selector reaches its normal position, the tripped brush is reset.

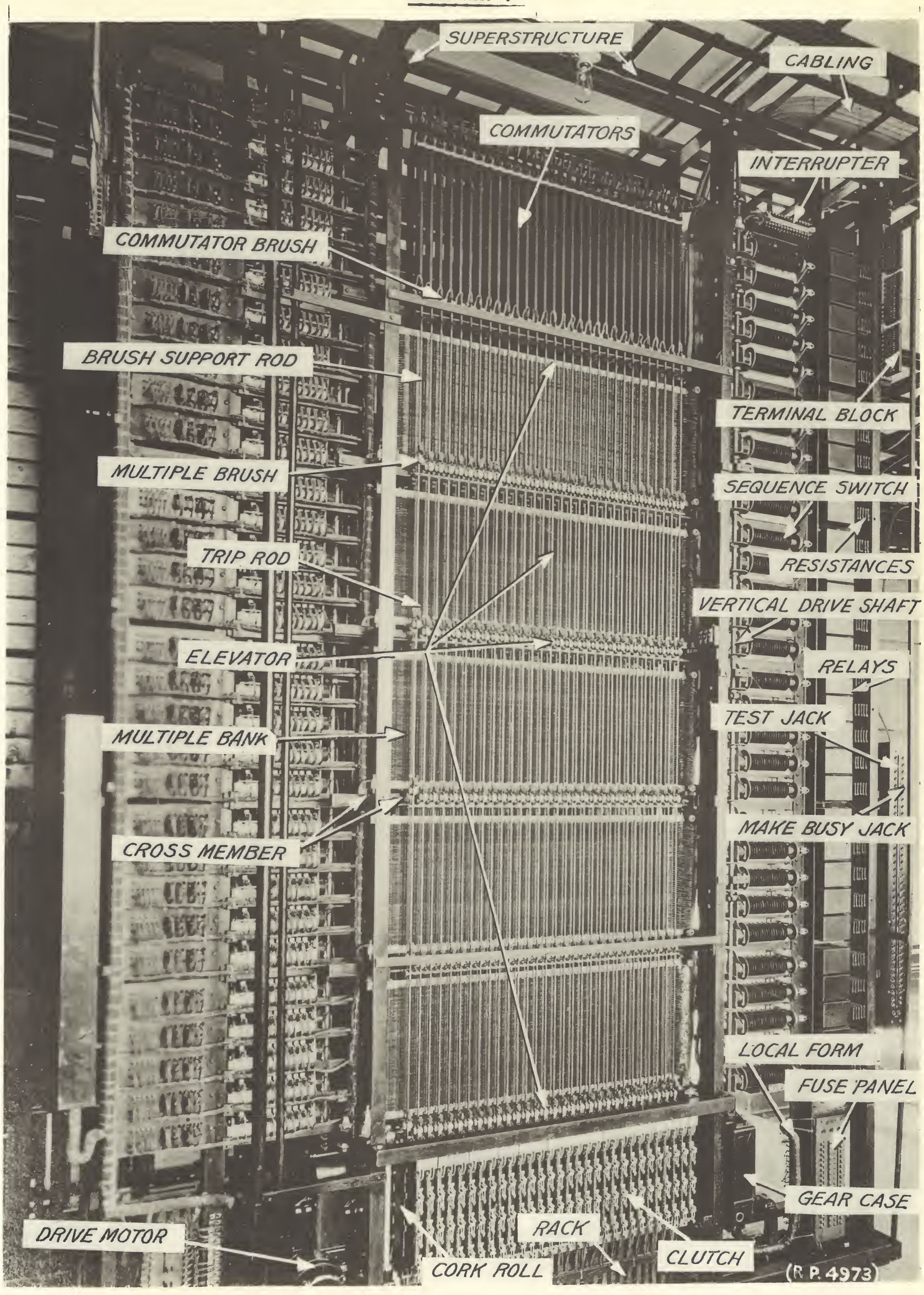

SUPERSTRUCTURE
CABLING
COMMUTATORS
INTERRUPTER
COMMUTATOR BRUSH
BRUSH SUPPORT ROD
TERMINAL BLOCK
MULTIPLE BRUSH
SEQUENCE SWITCH
TRIP ROD
RESISTANCES
VERTICAL DRIVE SHAFT
ELEVATOR
RELAYS
TEST JACK
MULTIPLE BANK
MAKE BUSY JACK
CROSS MEMBER
LOCAL FORM
FUSE PANEL
GEAR CASE
DRIVE MOTOR
RACK
CLUTCH
CORK ROLL
(R.P. 4973)

Fig. 52

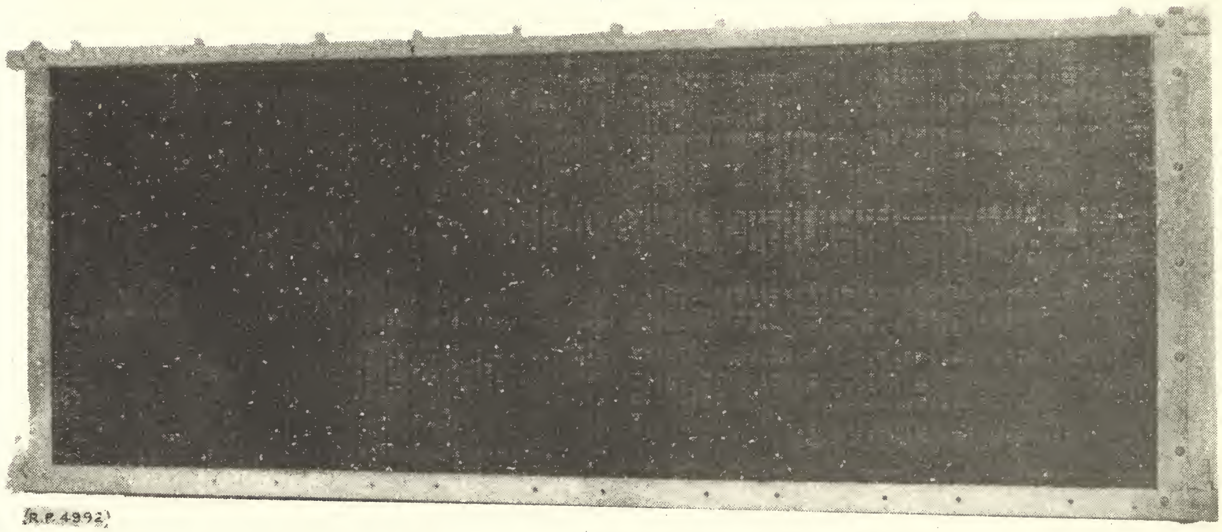

(R.P.4992)

Fig. 53

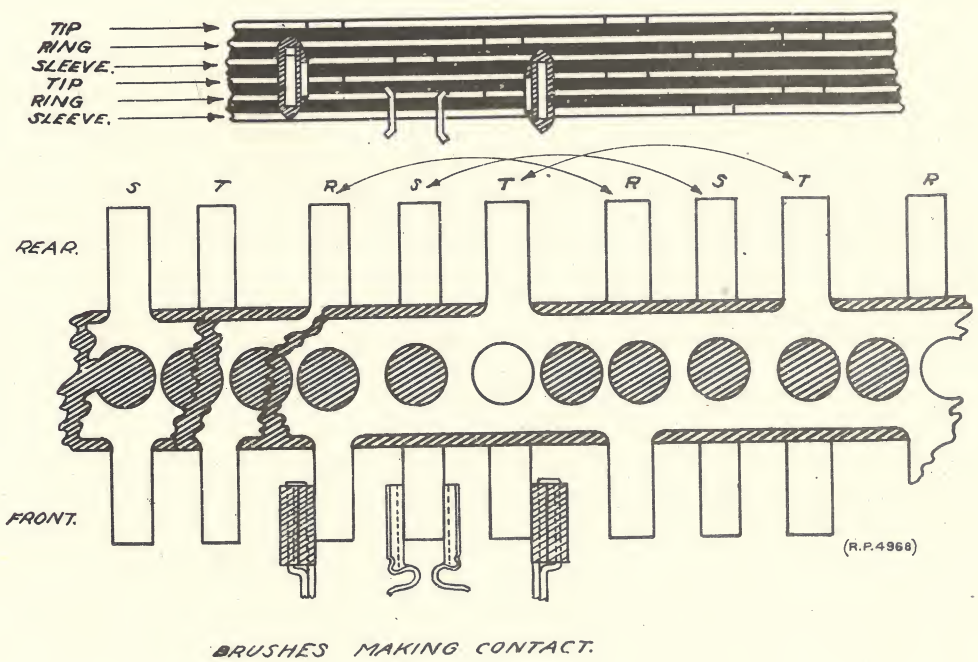

TIP
RING
SLEEVE.
TIP
RING
SLEEVE.
S
T
R
S
T
R
S
T
R
REAR.
FRONT.
(R.P.4968)
BRUSHES MAKING CONTACT.

Fig. 54

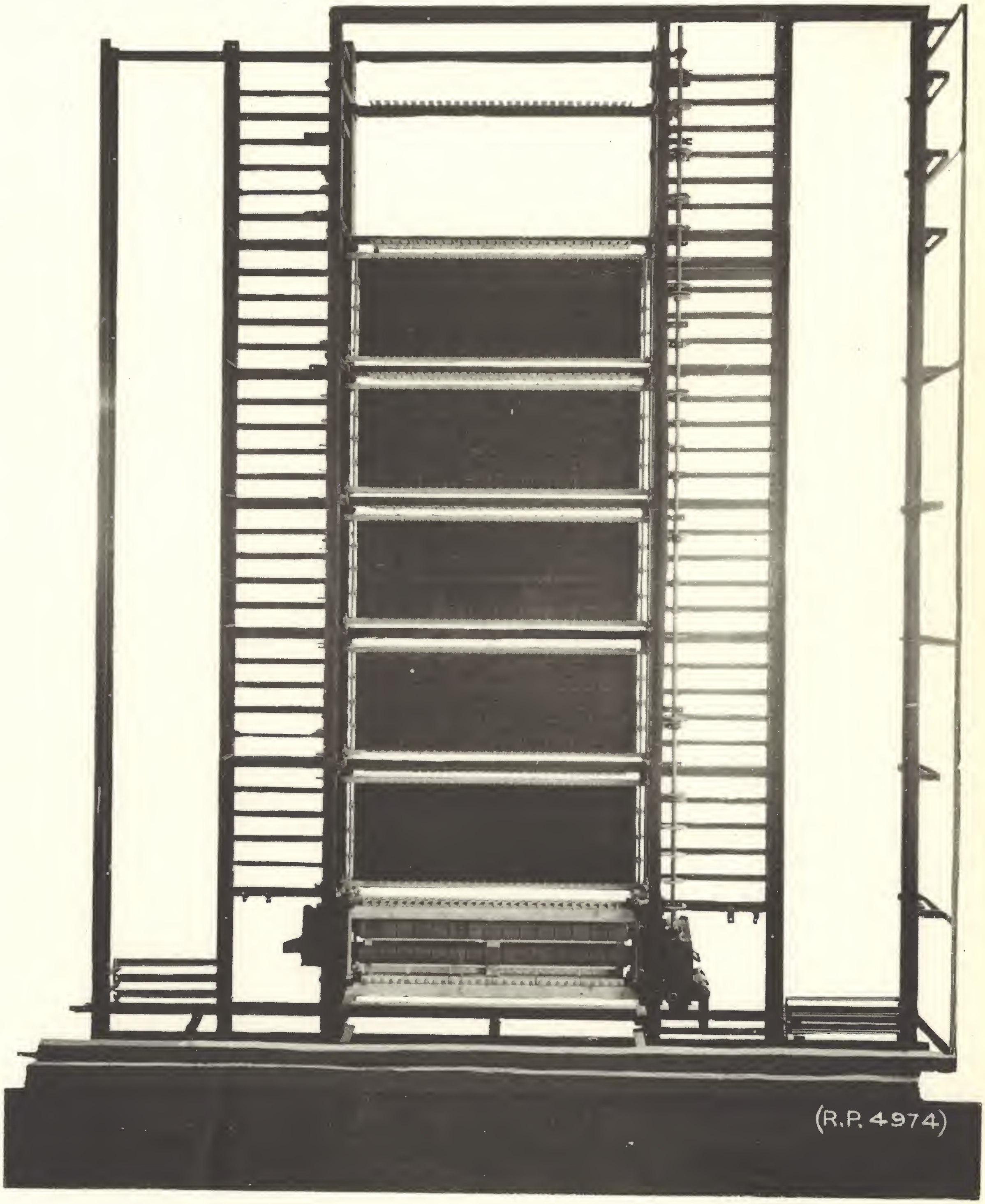


Fig. 55

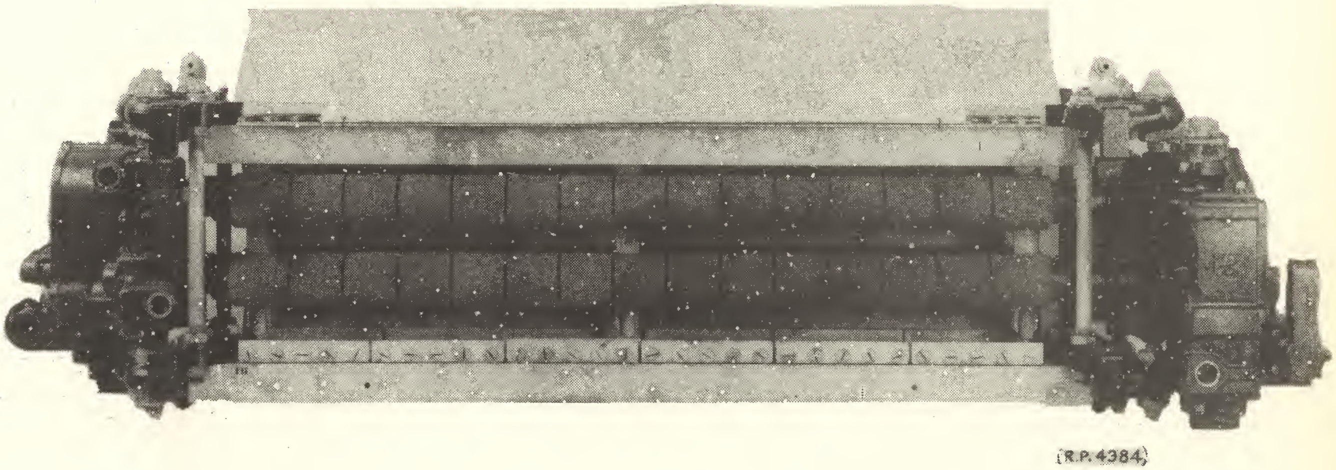


Fig. 56

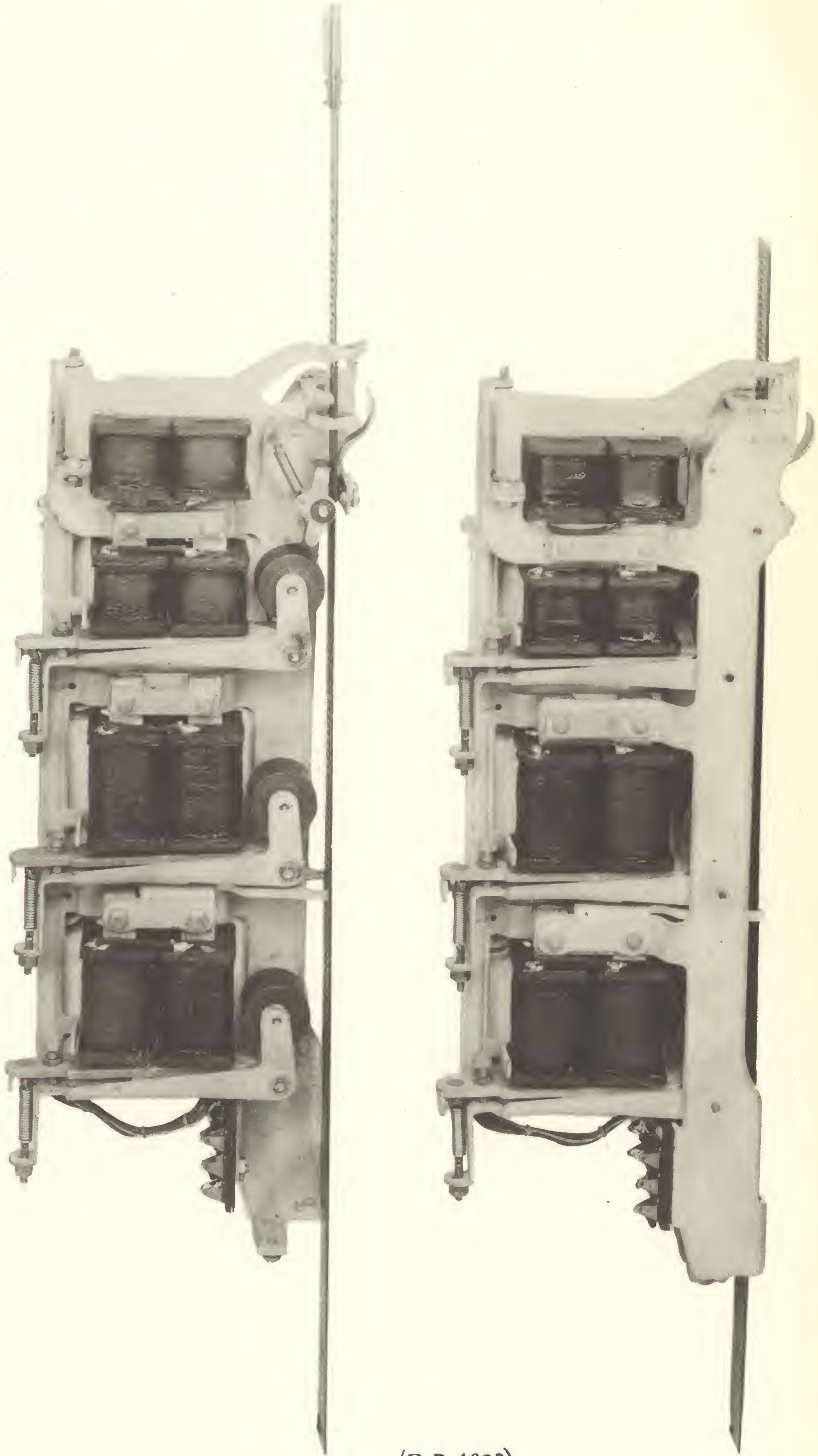
The tripping of the desired brush is accomplished by means of the trip rod and its associated trip fingers. The trip rod is a small metal rod mounted vertically, directly behind the selector rod and arranged so that it can be rotated, but held rigid as regards up and down movement. The trip rod has a trip finger associated with each multiple brush but each trip finger is set at a different height relative to its associated brush.

In selecting a particular brush, the up-drive magnet operates, moving the elevator upward a number of steps, corresponding to the brush desired, that is, one step for the first brush and two steps for the second brush, etc. The clutch magnet then releases, stopping the upward movement of the elevator. The trip lever of the desired brush is directly opposite its trip finger while the trip levers of the other brushes are either above or below their respective trip fingers. The various positions of the trip fingers and brushes are shown in Fig. 60.

The trip magnet which is located on the clutch frame immediately above the down-drive magnet, now operates and causes the trip rod to rotate, and the trip lever of the desired brush to be engaged by its trip finger which is directly opposite it. The trip fingers are equipped with small coil springs, thus preventing more than one trip finger from engaging with its trip lever at one time. The trip finger so engaged is stopped half way through its normal arc of travel, the coil spring allowing the trip finger to remain stationary while the trip rod continues to rotate through its complete arc of travel, carrying the other trip fingers around with it. The elevator now continues its upward movement and the brush whose trip lever has engaged its trip finger will be tripped.

At the top of the frame, just above the 5 banks are located commutators as shown in Fig. 61, one for each selector. The multiple wiring of the brushes on the selector leads to other brushes which move over strips on these commutators and thereby completes the connection from the movable selector to the rest of the circuit, thus avoiding flexible wire connections with their attendant troubles. This commutator also performs the more important service of controlling the travel of the selector. Brushes moving over conducting segments separated by insulation produce impulses which control the selector travel.

Another device of great importance is the sequence switch shown in Fig. 62. It is operated through an electromagnetic switch from the same motor that drives the selectors. The way in which this operates is more clearly illustrated by the diagram in Fig. 63. The sequence switch is turned on its shaft by energizing the magnet "R" which pulls the flexibly mounted disc on the sequence switch shaft against the edge of the rotating drive disc on the vertical shaft. The sequence switch may be described as a circuit controller whose function it is to establish in a definite sequence such circuit conditions as are required in the operation of the system. It is made up of circular discs called cams, mounted rigidly on a shaft. The plates of



(R.P. 4993)

Fig. 57

the cams are cut so that brushes come in contact with the plates only when the circuit is to be closed. The sequence switch can be stopped at any one of the 18 different positions as required, by the simple opening of the electromagnetic clutch. There are many of these sequence switches used in this system and the cuttings of the cams vary, depending upon the particular circuit combination which it is desired to establish.

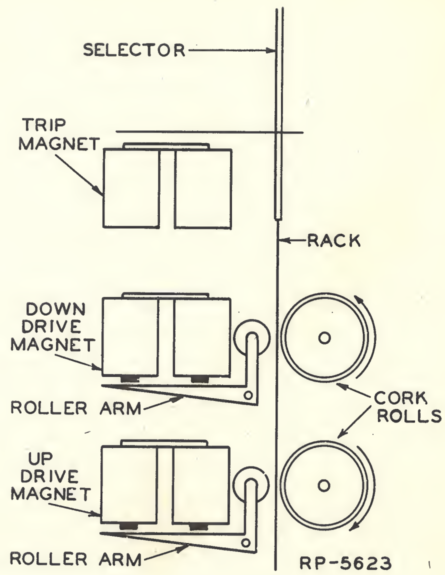


Fig. 58

Another selector frame of a slightly different type is the line finder frame illustrated in Fig. 64. It is on the banks of this frame that the subscribers' lines terminate, corresponding to the answering jacks in an "A" switchboard. It is the line finder selectors which select or find the line of a subscriber who has originated a call. There are 10 multiple banks each having a capacity of 40 lines, making a total of 400 lines on a frame. The line finder itself is a power driven selector very similar to the kind used on selector frames, except that it has 10 brushes instead of 5. The method of driving the selector is the same but the device for tripping the brushes is different.

On a line finder frame the trip rods are horizontal instead of vertical. Associated with each bank is a pair of trip rods, one on the front and one on the rear. The trip rods are rotated in pairs by the trip magnets. Firmly attached to each trip rod are a number of trip fingers, one for each line finder in the group on the same side of the frame. These trip fingers are small metal tongues with a rectangular slot in each. The relation of the trip rods and trip fingers to the multiple banks and brushes is shown in Fig. 65.

The operation of the selectors is controlled by another circuit known as the "sender". It is in effect the brains of the system, dealing with the subscriber and controlling the selection until the destination is reached, as an operator deals with the subscriber and controls the selection in a manual system. The number dialed conveys the same information to the sender in a machine switching system as the number spoken by the subscriber does to an operator in a manual system. The sender is an arrangement of relays, sequence switches and selectors so worked out as to perform the following more important functions:

1. It receives a succession of electrical impulses from the subscriber's dial which are on a decimal basis, stores them and translates them to a non-decimal basis, corresponding to the particular group of lines and trunks that is involved in the path of the call.

2. It controls selecting mechanisms which build up the connection to the called party in such a manner that each mechanism is given the exact time required to

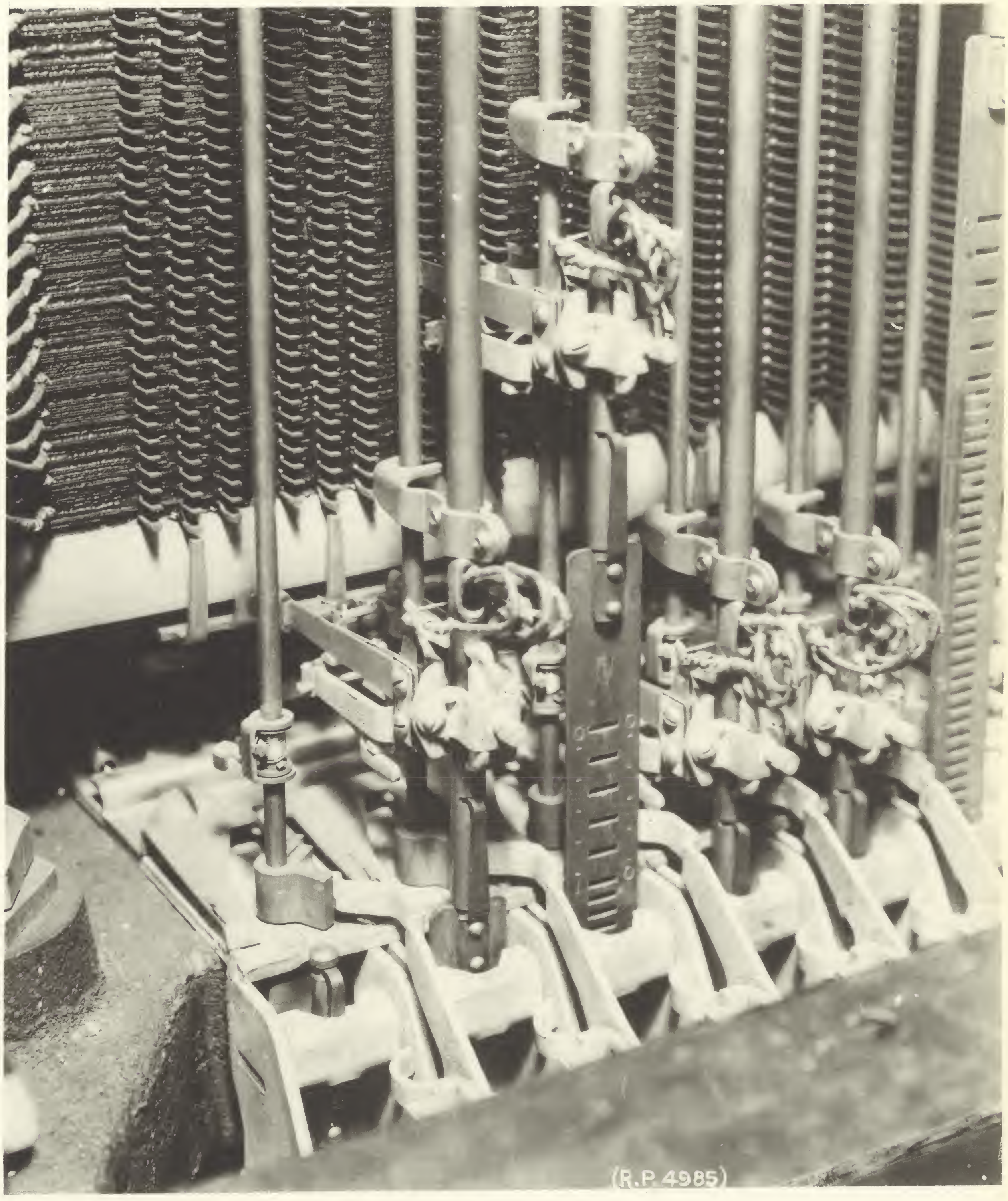
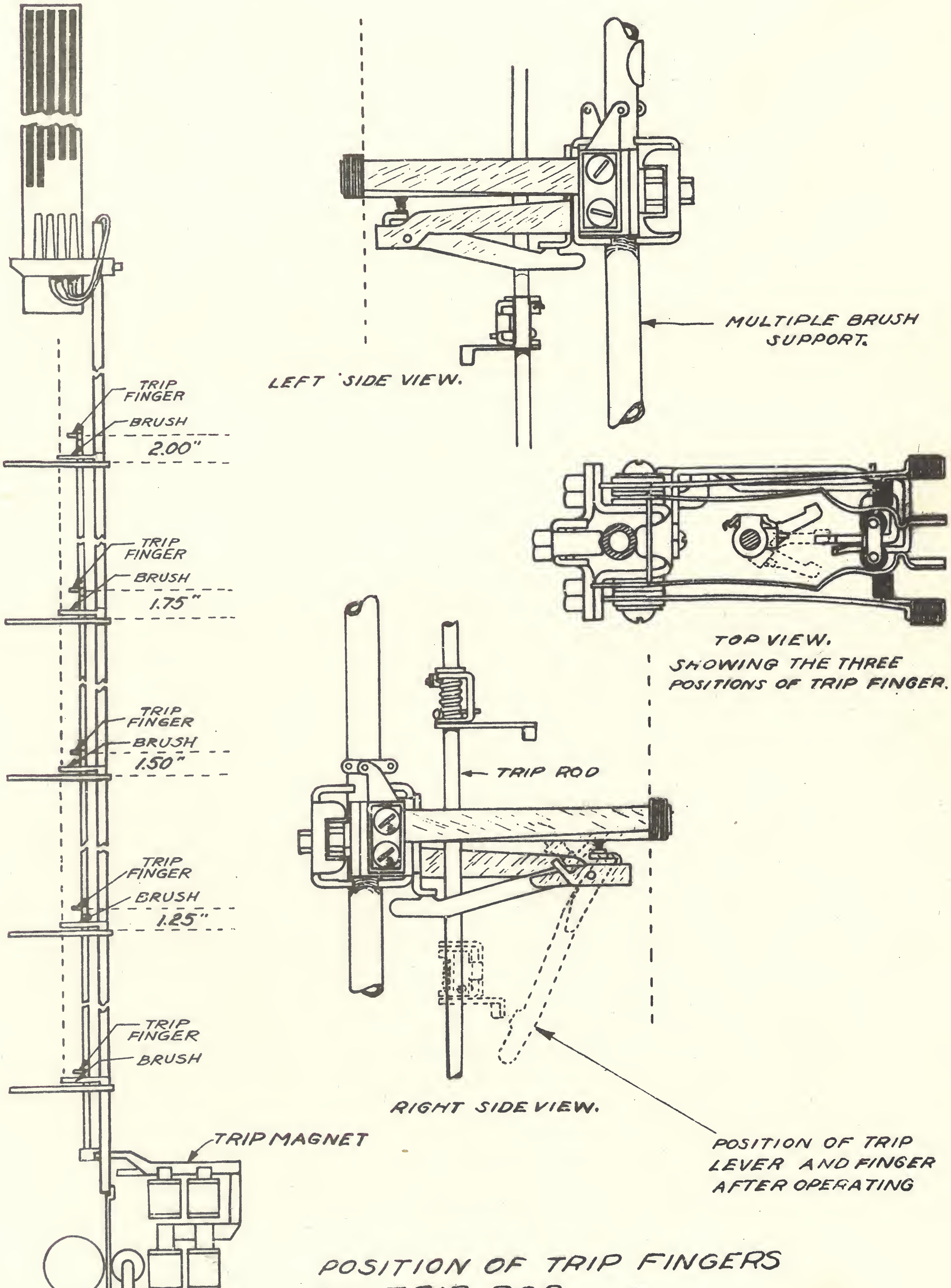


Fig. 59



POSITION OF TRIP FINGERS ON TRIP ROD.

(R.P.4970)

Fig. 60

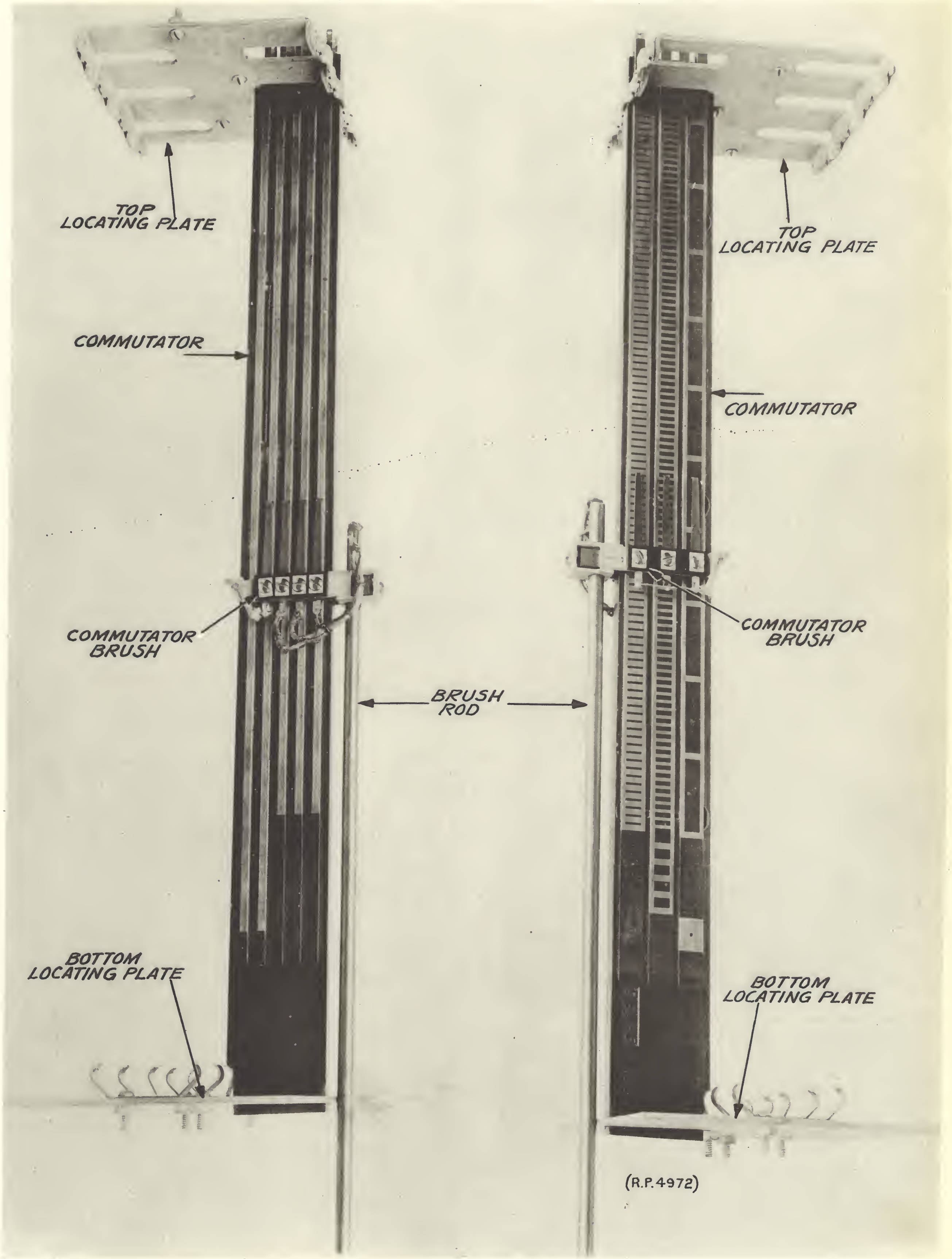

TOP LOCATING PLATE
COMMUTATOR
COMMUTATOR BRUSH
BOTTOM LOCATING PLATE
BRUSH ROD
TOP LOCATING PLATE
COMMUTATOR
COMMUTATOR BRUSH
BOTTOM LOCATING PLATE
(R.P.4972)

Fig. 61

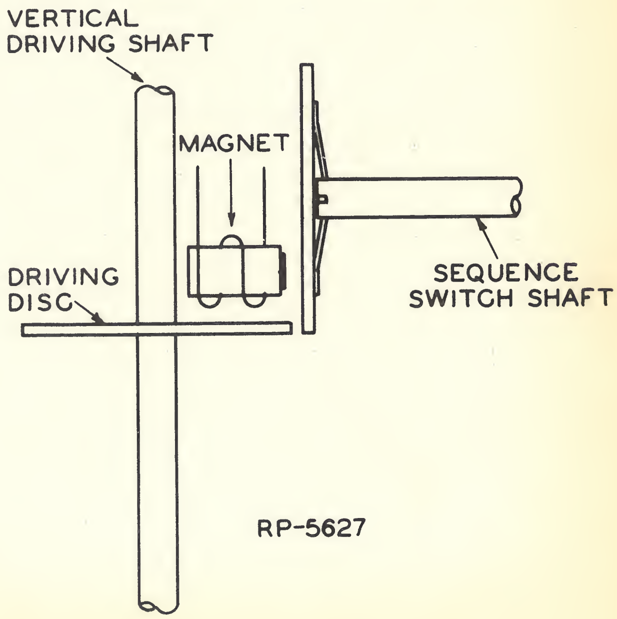
Fig. 62

perform its functions without any waste of time, independently of the rate received from the dial.

3. It makes the central office designations entirely independent of the arrangement of the trunk groups on the selector frames. This is a very important matter, inasmuch as it allows the selectors to be used to full efficiency. It provides the desired flexibility for growth and permits any desirable rearrangement of the trunks on the selector frames that the telephone company may find desirable at any time.

4. The sender is capable of distinguishing the class of office at which the connection terminates. That is, if the call is to terminate at a mechanical office, the sender will arrange to govern the selection accordingly. If the call is to terminate at a manual office, the sender recognizes this and arranges to send out impulses to the call indicator equipment in the manual office.

A sender frame is pictured in Fig. 66. There are 5 sender circuits mounted in units on a frame. The relays are enclosed in a cabinet, and a close-up of the cabinet with the doors open is shown in Fig. 67.



Another piece of apparatus that is used extensively for various purposes in the panel machine switching system is the rotary switch or 200 type selector. This is illustrated in Fig. 68, and in Fig. 69 is shown a diagram illustrating the principle upon which it operates. A double ended set of brushes is caused to pass over the contacts on a semi-circular bank by opening and closing the circuit of the magnet. The circuit to the magnet is carried through a set of contacts which are opened and closed by the operation of the armature. When the magnet is energized, the resulting motion of the armature opens the circuit at the contacts and releases the armature which, upon returning to normal, pushes the ratchet wheel and brush assembly one step from one terminal to the next. When the armature is returned to normal, the contacts are again closed so that the magnet again energizes and repeats the operation. In this way the switch continues to step from one terminal to the next so long as the current is applied. A similar action can be made to take place by interrupting the circuit from an outside source. A common use for these switches is for storing the dial pulses in the sender circuit.

Another important element in the panel machine switching system is the translator frame shown in Fig. 70, and its associated pulse machine shown in Fig. 71. The purpose of the translator and pulse machine is to translate the

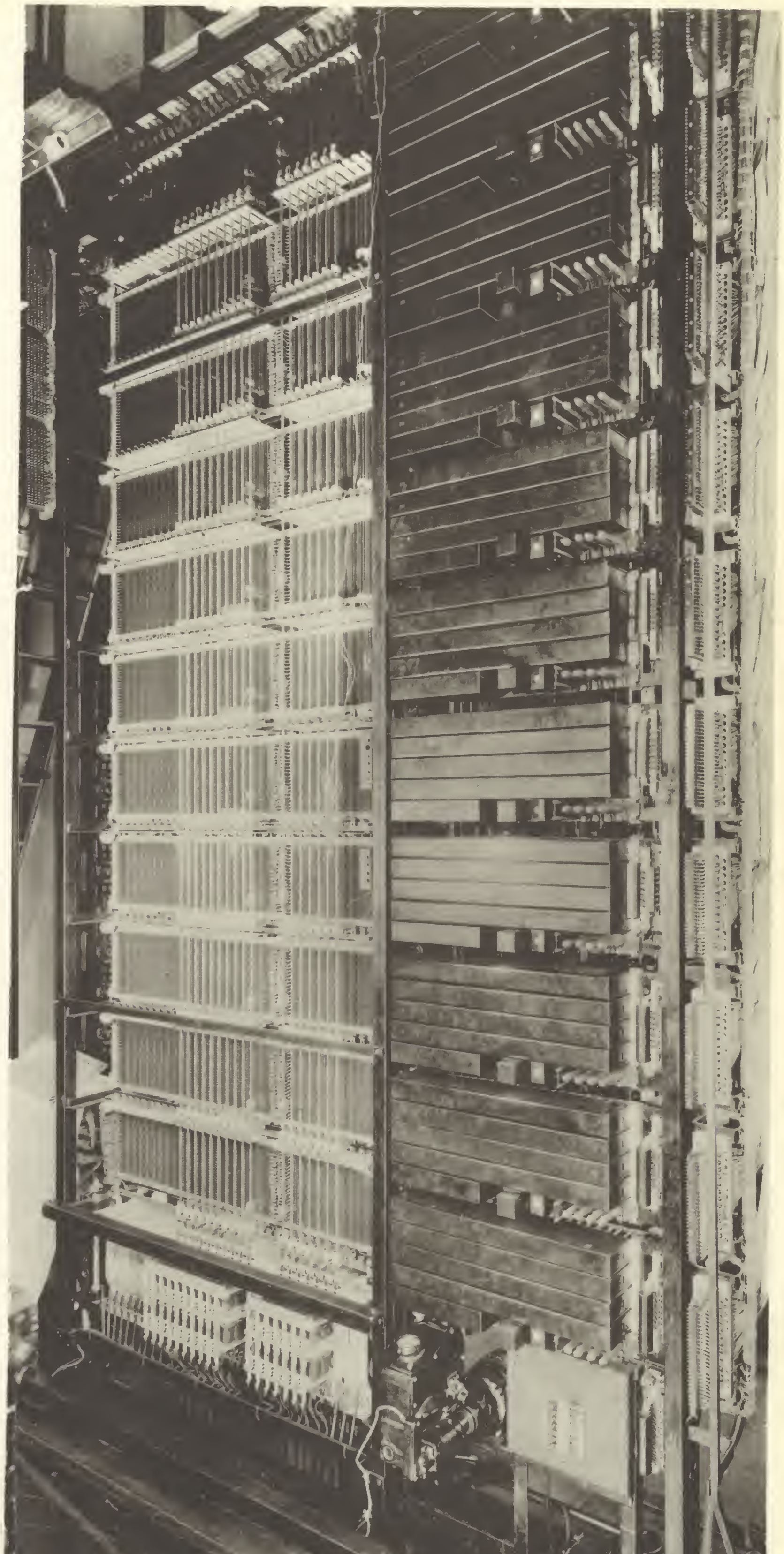


Fig. 64

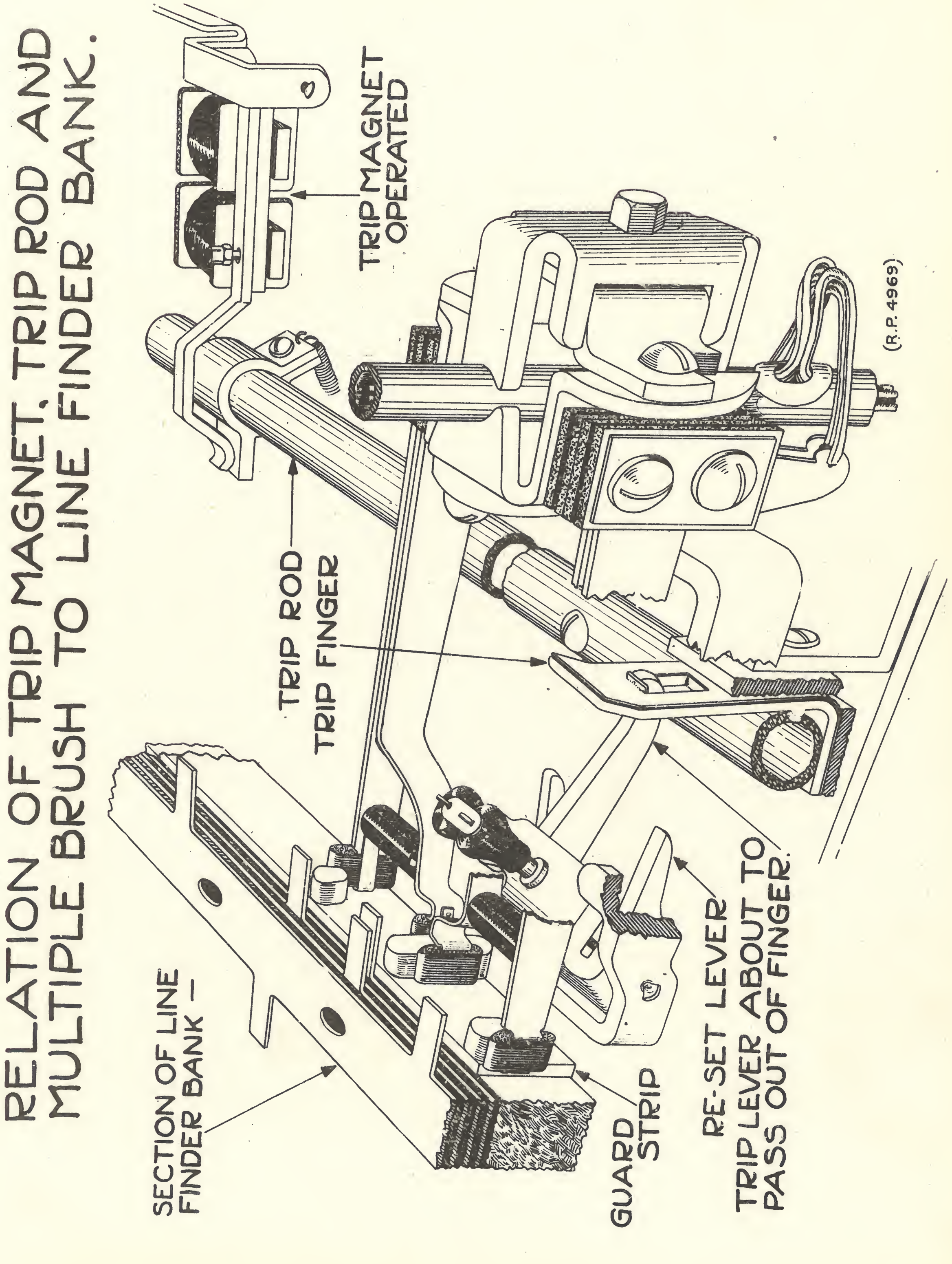

RELATION OF TRIP MAGNET, TRIP ROD AND MULTIPLE BRUSH TO LINE FINDER BANK.
TRIP MAGNET OPERATED
TRIP ROD
TRIP FINGER
(R.P. 4969)
SECTION OF LINE FINDER BANK –
GUARD STRIP
RE-SET LEVER
TRIP LEVER ABOUT TO PASS OUT OF FINGER.

Fig. 65

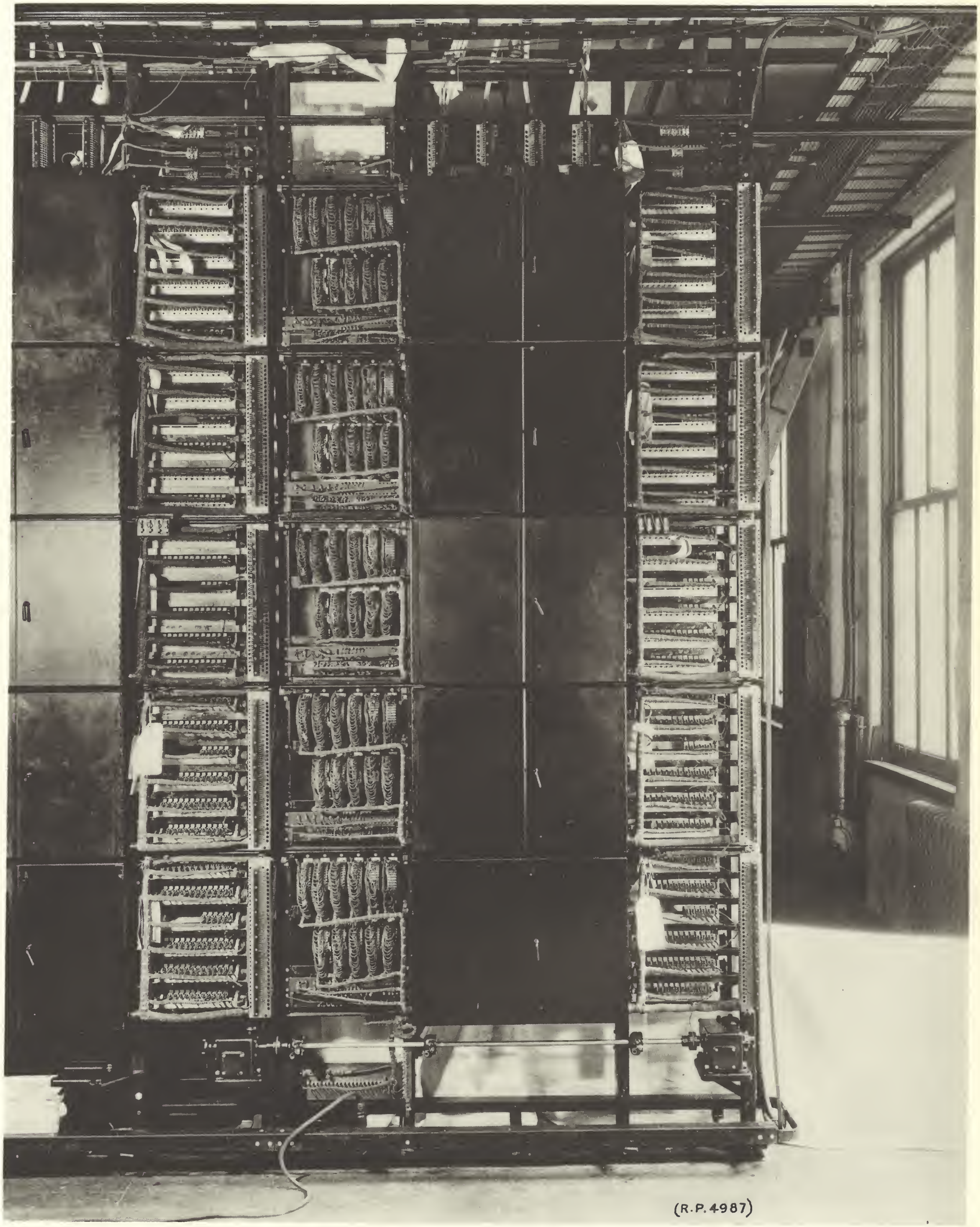


Fig. 66

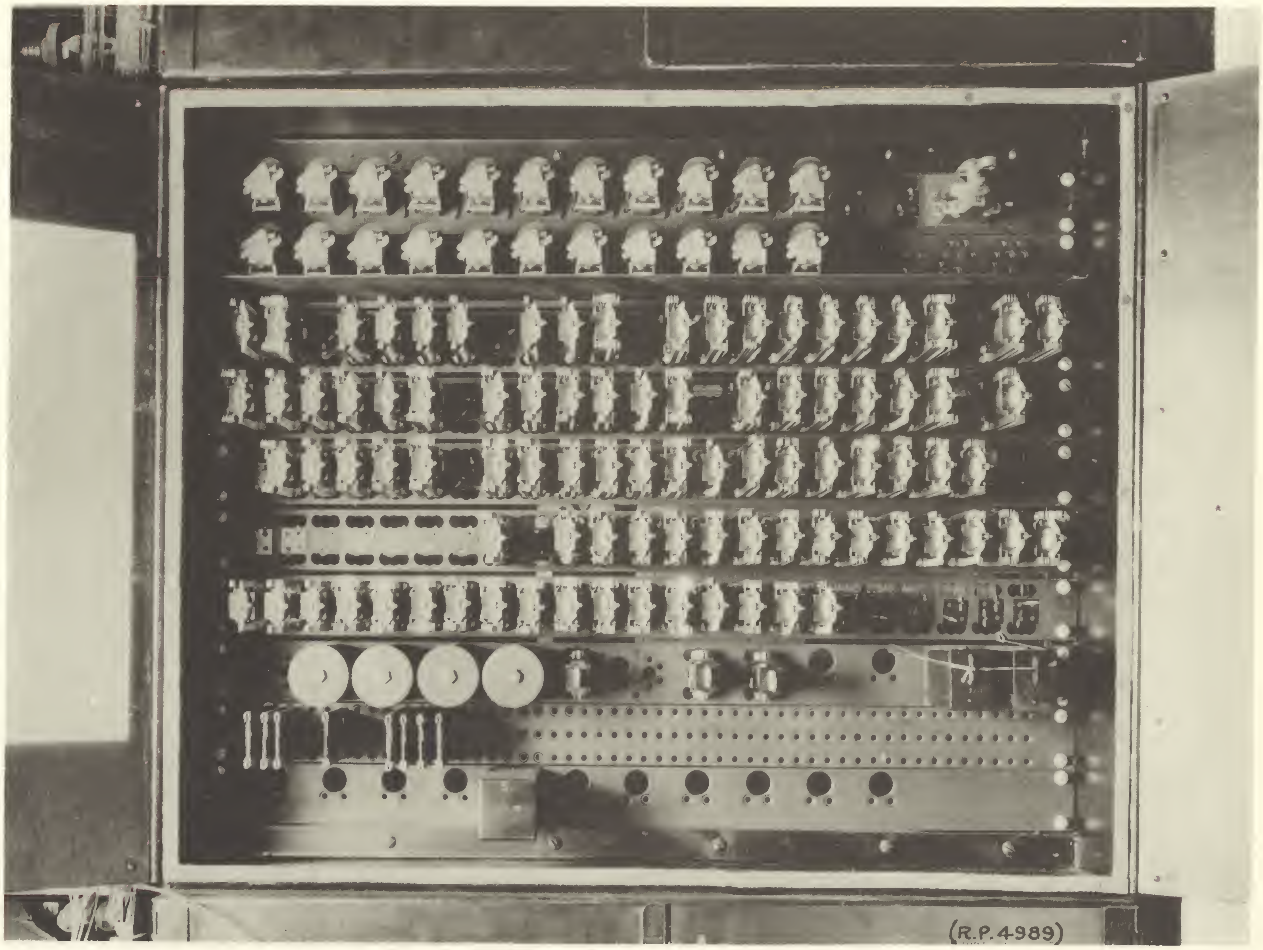


Fig. 67

number dialed into the proper selections required for controlling the operation of the selectors. There are 10 multiple banks of 40 circuits each to which 60 selectors, 30 on each side, have access.

The pulse machine is a motor driven interrupter of 4 drums, for supplying interrupted current in the proper sequence and is wired to the multiple banks of the translator through a distributing frame so arranged as to provide maximum flexibility of connections.

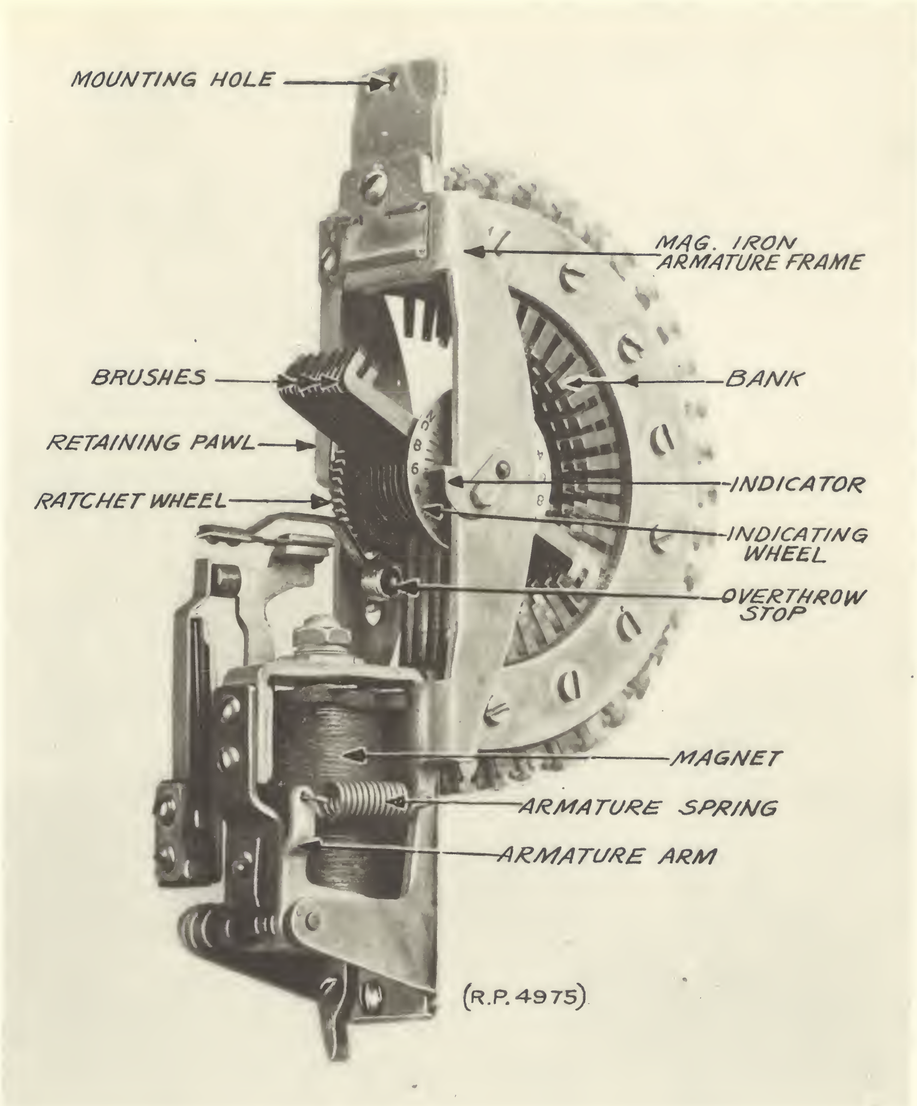

MOUNTING HOLE
MAG. IRON ARMATURE FRAME
BRUSHES
BANK
RETAINING PAWL
RATCHET WHEEL
INDICATOR
INDICATING WHEEL
OVERTHROW STOP
MAGNET
ARMATURE SPRING
ARMATURE ARM
(R.P. 4975)

Fig. 68

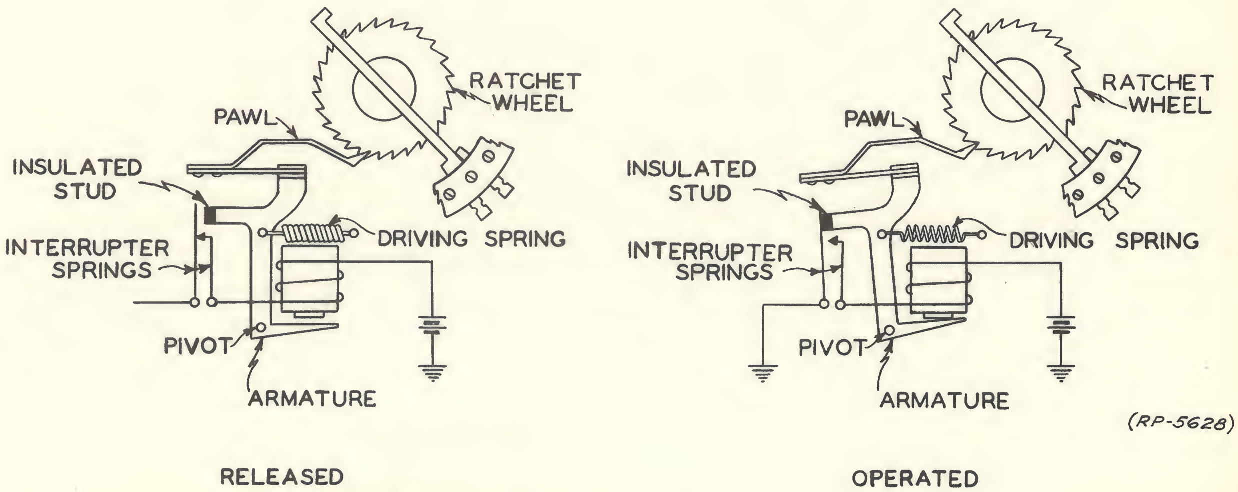

RATCHET WHEEL
PAWL
INSULATED STUD
DRIVING SPRING
INTERRUPTER SPRINGS
PIVOT
ARMATURE
RELEASED
RATCHET WHEEL
PAWL
INSULATED STUD
DRIVING SPRING
INTERRUPTER SPRINGS
PIVOT
ARMATURE
OPERATED
(RP-5628)

Fig. 69

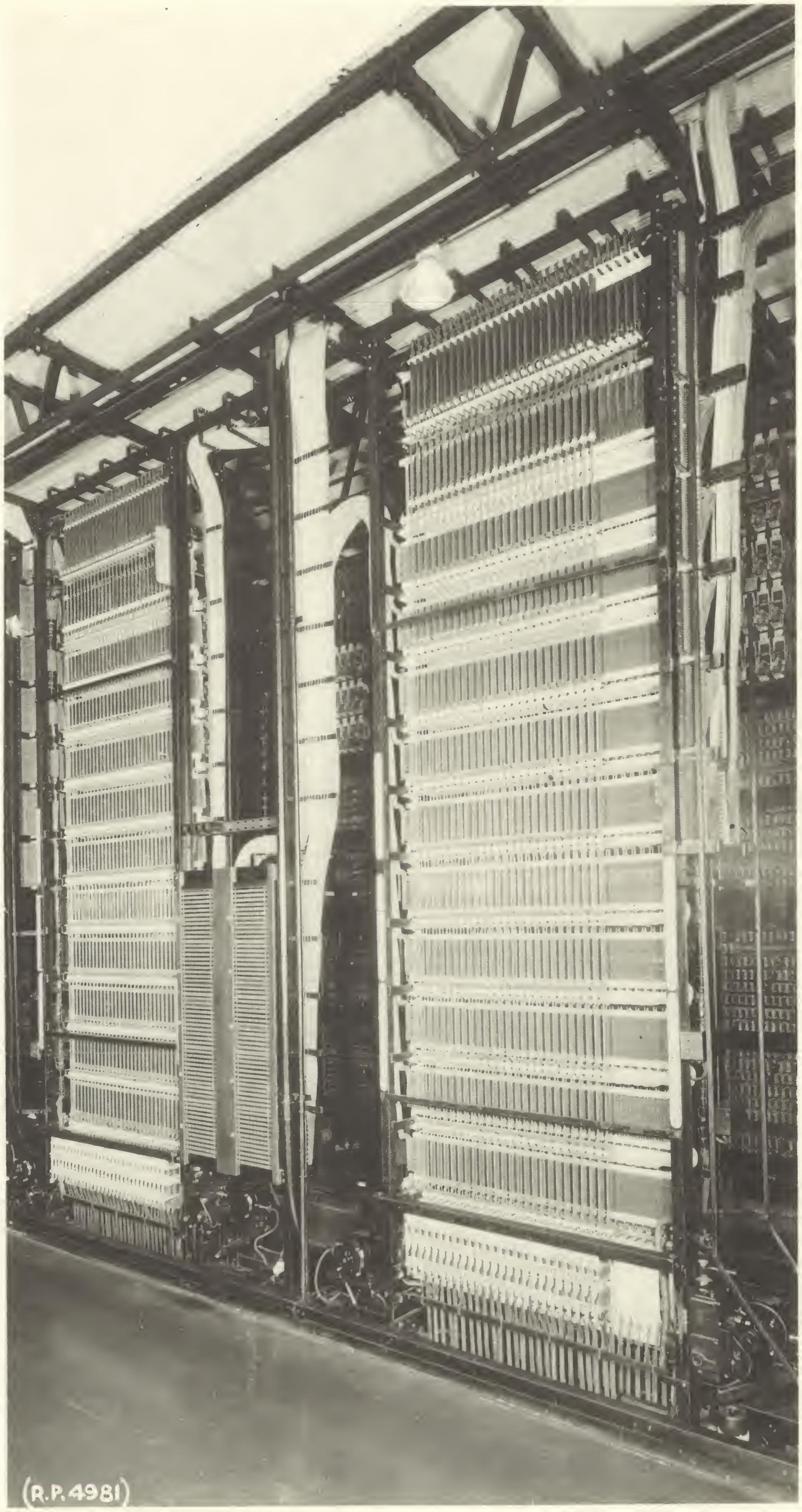


Fig. 70

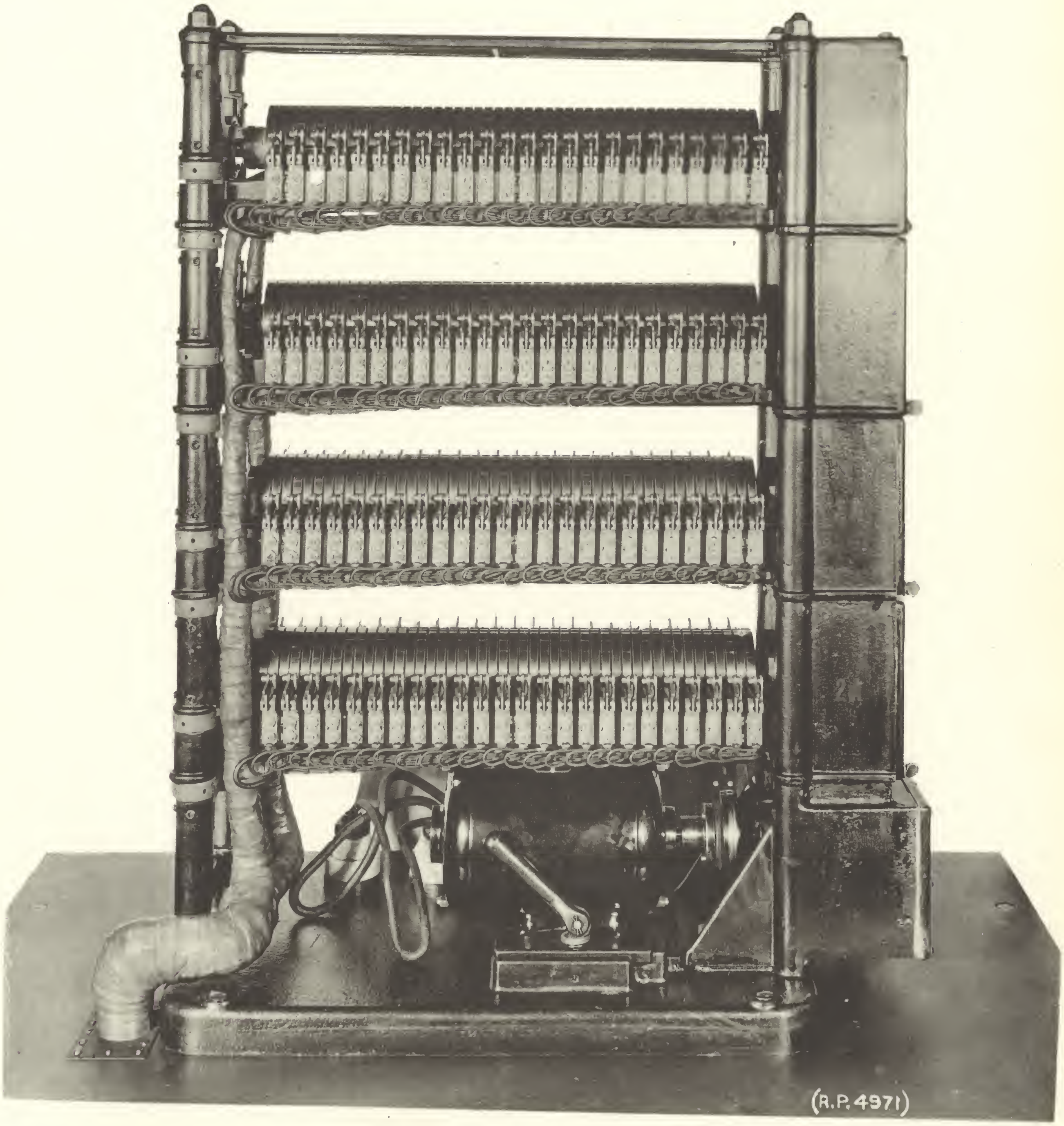


Fig. 71

CHAPTER VI - PANEL MACHINE SWITCHING CALLS

There is a fairly close analogy between the functioning of the machine switching and manual circuits. Referring to Fig. 72, let us trace a call and note this similarity. The pair of wires from a subscriber's telephone is attached to one of the sets of fixed terminals in a panel bank of a line finder frame: the terminals correspond to the answering jacks and the selectors to the "A" operator's answering cords of the manual system. When the subscriber removes his receiver he closes the circuit of his line, causing a relay at the central office in series with his line to operate. This relay causes an idle line finder, having access to his line, to trip the proper brush and then move upward to his line. At the same time, a sender selector attached to that line finder is choosing, out of a common group, an idle sender. A rotary selector or 200 type selector is used as this sender selector. The sender having been attached in this manner to the calling line, a low humming sound, known as "dial tone" is heard by the subscriber, advising him that the mechanism is ready for him to dial. The entire sequence of events just described takes place in a fraction of a second, so that ordinarily the subscriber finds the dial tone when the receiver reaches his ear. The subscriber now dials the required letters of an office name and the numerals of the called number. The pulses from the dial travel over the subscriber's line through the line finder and sender selector to the sender which records or translates them to control the setting up of a connection. As soon as the connection has been established, the sender is released and is ready to be used for a new call, being kept in use only a few seconds for each call.

The first step in completing the connection is to choose an idle trunk to the desired central office. Directly associated with each line finder is another panel selector known as a district selector. This district selector has capacity for 450 working outgoing trunks, the other 50 trunks being used for control purposes.

In a small city, 450 trunks would be sufficient to reach all points, but in the case of large cities, 450 outgoing trunks are not sufficient. Accordingly, only a few of the trunk groups outgoing from these offices leave directly from the district selectors. To obtain access to the remaining trunks, there are, on every district selector frame, groups of trunks leading to office selectors. These office selectors are selectors of the panel type and each has a capacity of 450 outgoing trunks. For the sake of simplicity we will omit the office frame in tracing the call. The district selectors start upward under the control of the sender. As the district selector moves upward, it produces pulses by means of the brushes which slide over the commutator at the top of the selector. These pulses are transmitted back to the sender and are there counted. When the sender has counted a number of pulses which indicate to it that the district selector has proceeded to the proper position, the sender opens the fundamental circuit to the selector and causes it to stop. This method of controlling the movement of the selector is termed the "reverse control method".

The first selection made chooses the set of brushes to be tripped into engagement with the terminals. Assume, as shown in Fig. 72, that the desired trunk appears on the 4th panel from the bottom; therefore, the district selector is allowed to make 4 pulses and is then stopped by the sender. The brush-tripping

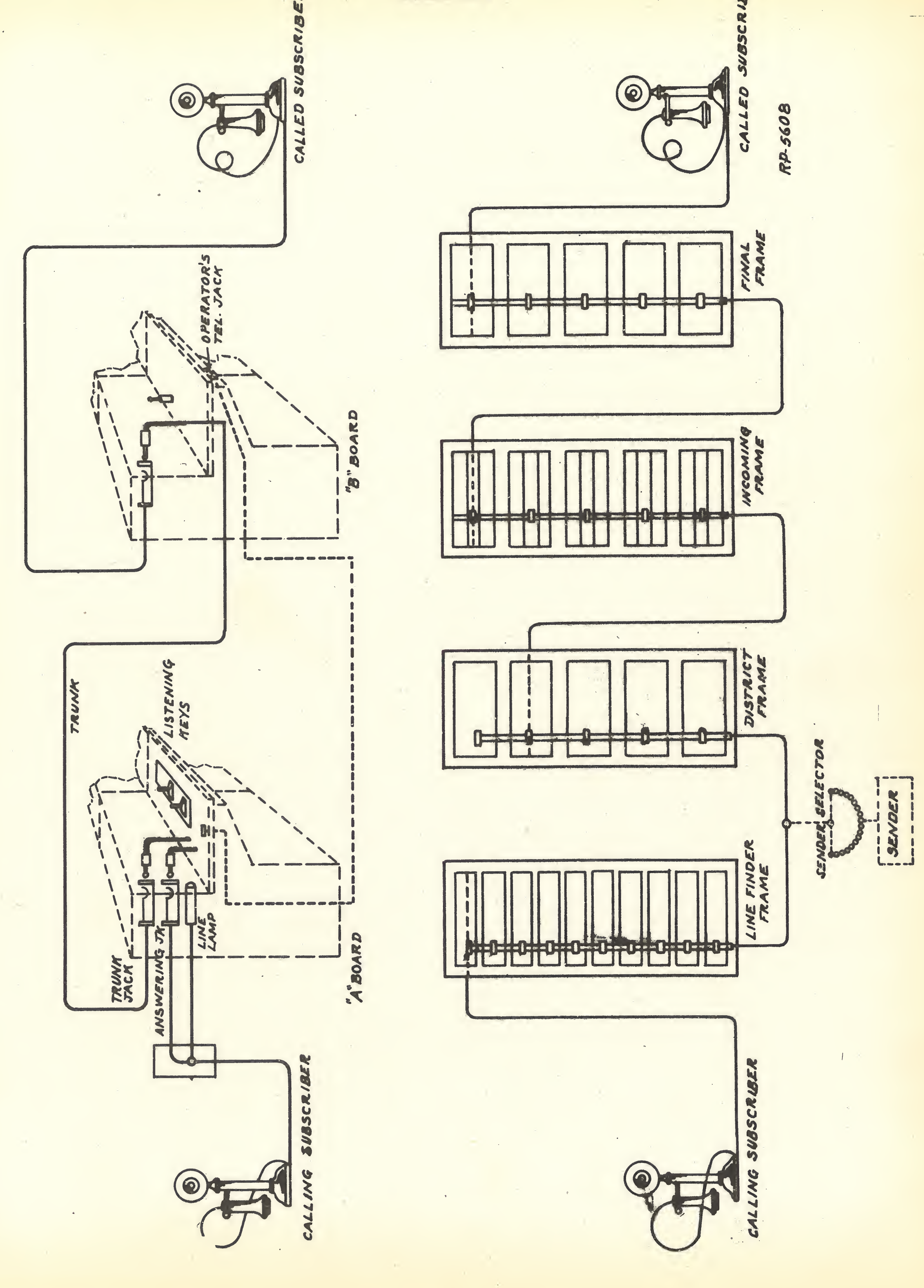

CALLING SUBSCRIBER
ANSWERING JK.
LINE LAMP
TRUNK JACK
LISTENING KEYS
TRUNK
"A" BOARD
OPERATOR'S TEL. JACK
"B" BOARD
CALLED SUBSCRIBER
CALLING SUBSCRIBER
LINE FINDER FRAME
SENDER SELECTOR
SENDER
DISTRICT FRAME
INCOMING FRAME
FINAL FRAME
CALLED SUBSCRIBER
RP-5608

Fig. 72

device is thus set in position to trip the 4th brush, and the selector is started again by a signal from the sender, which operation completes the process of tripping the brush.

The selector now continues upward, making a pulse for every group of trunks which it passes over until, having reached the desired group, as indicated by the number of pulses counted by the sender, it is again stopped by the sender at the beginning of this group. The selector is now started again, and this time under its own control hunts for an idle trunk in the group. Busy trunks are grounded on the third or sleeve terminals, whereas idle trunks are open. A testing relay, associated with the selector, keeps the selector moving upward until a trunk with an open sleeve wire is found, whereupon the selector stops, makes connection with this trunk, and renders it busy to other selectors by grounding the signalling strip. The connection is now extended to an outgoing trunk. The sender still remains attached to the connection since it must still control the further setting up of the connection.

The sizes of the working trunk groups on district and office selectors can vary from 5 to 90, depending upon the traffic to be handled.

The incoming trunk to the machine switching office terminates on an "incoming selector", which is of the type already described. A machine switching office has a capacity for 10,000 numbers, but the incoming selector has capacity of only 500 trunks, so that the same arrangement is employed as on the district selectors; that is, the incoming selector chooses one of a number of other selectors, called "final selectors", which have access to the subscribers' lines. Since each final frame has a capacity of 500 subscribers, 20 frames will be required to care for the full 10,000 numbers. On the incoming selector frames, therefore, appear 20 groups of trunks, each group leading to a different frame of final selectors.

The method of selection is the same as described for the district and office selectors; that is, first the incoming selector, under control of the sender in the originating office, trips the proper brush, chooses the proper group, and finally chooses an idle trunk leading to a final selector. The final selector then goes through the process of brush, group, and subscriber's terminal selection. The terminal selection is under the control of the sender which counts line by line in the group of ten, until the desired one is reached. If the called line is idle, it is rung, and the calling subscriber is advised of that fact by hearing the audible ringing signal. If the called line is busy, it is not connected but an intermittent buzz, recognized as the busy signal, is sent back to the calling subscriber. If the called number is that of a P.B.X. having several trunks, the final selector automatically hunts for an idle one. If the final selector, after testing all the P.B.X. trunks, finds them all busy, it sends back the busy signal.

As soon as the called line is reached, the sender is dropped from the circuit to be available for another connection. It is not held during the period of ringing, during the time that the busy signal is being given, if the line is busy, or during any part of the period of conversation.

It will be noted that the method of selection is not on a decimal basis.

The first selection chooses one of five brushes on the incoming selector as already explained; that is, we choose that particular fifth of the terminals in which the called line happens to be and, since 1/5 of 10,000 is 2,000, we choose the 2,000 group desired. The next selection is by groups of 500, which is again non-decimal. This "translation", as it is called, of the number from the decimal notation, as dialed by the subscriber, into the notation as needed by the selectors, is taken care of very simply in the senders.

In Fig. 73 is shown how the letters and numbers dialed are translated into the various selections. It will be noted that the three letters determine the district brush and district group selection, and in case office frames are used, they also determine the office brush and office group selection.

The thousands digit determines the incoming brush selection and the thousands and hundreds digits together determine the incoming group selection. Final brush selection is determined by the hundreds digit. The tens and units remain unchanged.

A)
B) District Brush, District Group, Office Brush, Office Group.
C)

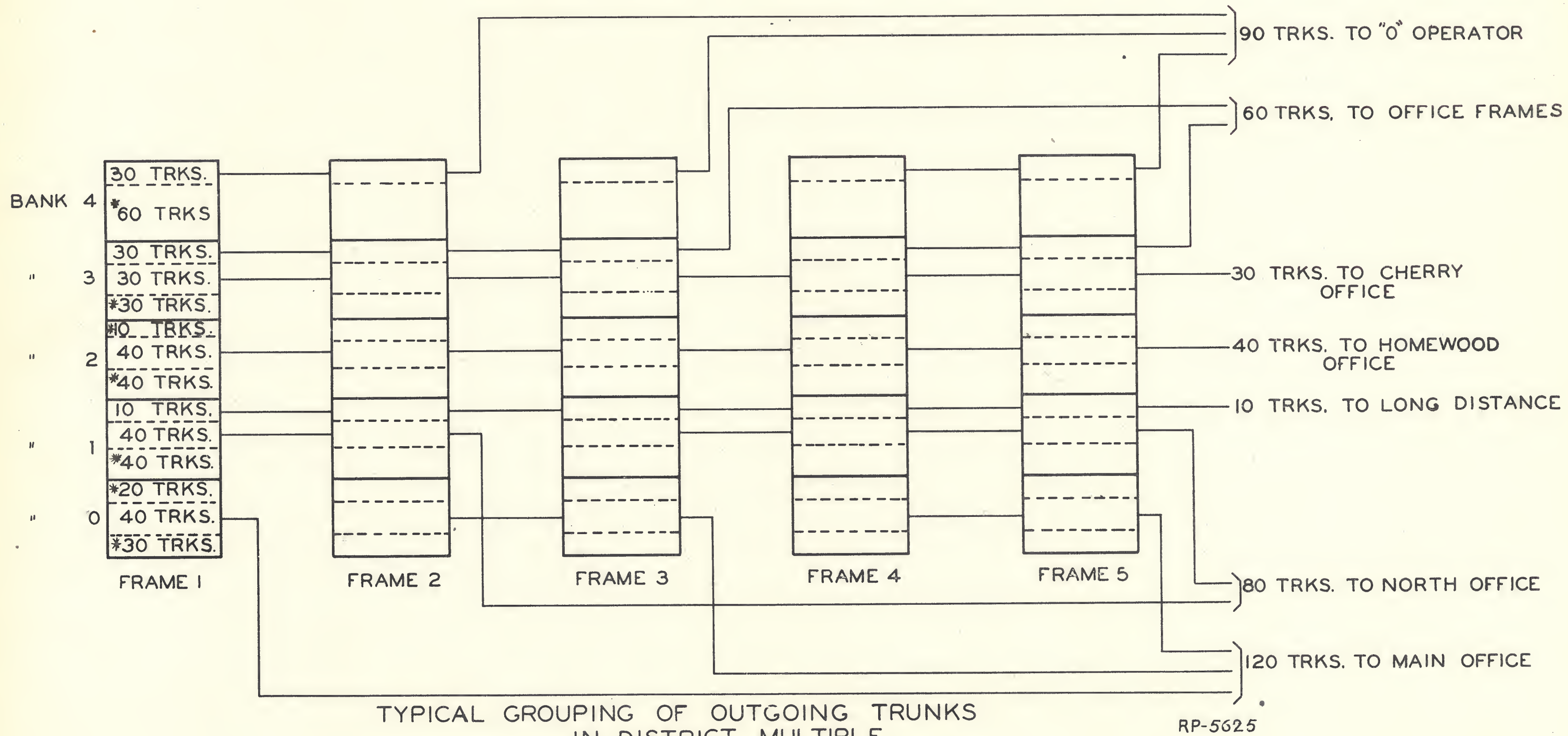
Thousands	Incoming Brush)	Incoming Group.
Hundreds	Final Brush)	
Tens	Final Tens	
Units	Final Units	

Fig. 73

In Fig. 74 is shown a typical arrangement of the district multiple. In this example five district frames are shown and the various groups of trunks are multipled from one frame to the other. It will be noted that in some cases the trunks are not multipled through all five frames. This is done where the traffic is so heavy that a single group of trunks will not suffice to take care of all the calls. This is the case, for example, with the trunks to main office where there are three groups of 40 trunks, making a total of 120 in all.

The cabling arrangement between the incoming frames and the final frames is a fairly fixed relation in view of the fact that in order to accommodate the 10,000 subscribers it is necessary to have 20 frames and that the selectors on these frames must terminate in a particular group on the incoming frames. This relation is shown in Fig. 75. A diagram illustrating this arrangement is shown in Fig. 76. It will be noted that No. 1 final frame accommodates lines from 0 to 499 and that the final selectors for this frame are connected to the zero group in the zero bank on the incoming frame. Similarly, the second final frame takes numbers from 500 to 999 and the selectors from this frame terminate in group No. 1 of incoming bank zero, and so on, for the rest of the frames.

In order that the machine switching system may render universal service, it is, of course, necessary to connect subscribers in machine switching offices with subscribers in manual offices.



TYPICAL GROUPING OF OUTGOING TRUNKS IN DISTRICT MULTIPLE.

GROUPS OF TRUNKS MARKED * OMITTED TO SIMPLIFY ILLUSTRATION.

Fig. 74

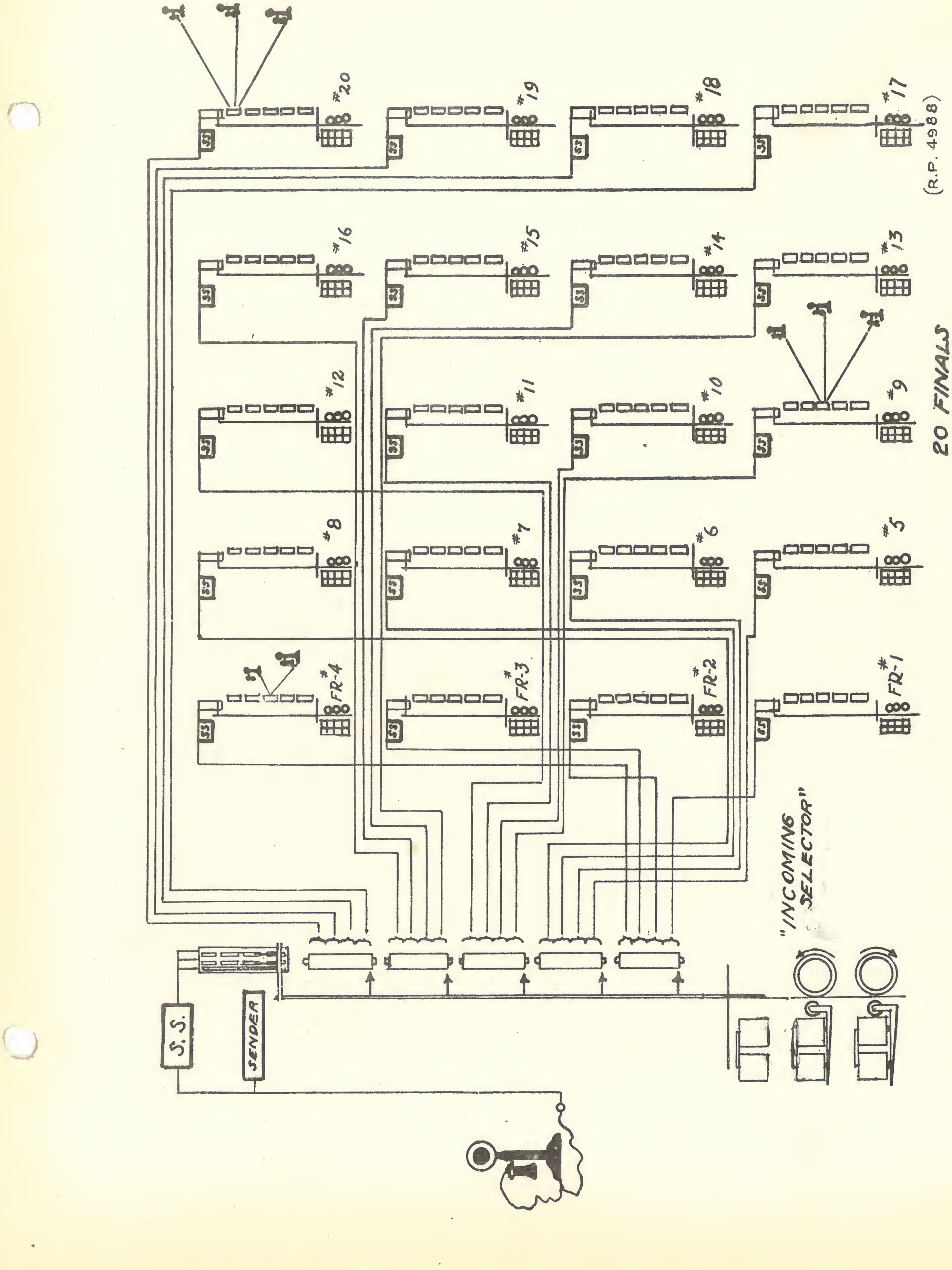

#20
#19
#18
#17
#16
#15
#14
#13
#12
#11
#10
#9
#8
#7
#6
#5
#FR-4
#FR-3
#FR-2
#FR-1
20 FINALS
"INCOMING SELECTOR"
S.S.
SENDER
(R.P. 4988)

Fig. 75

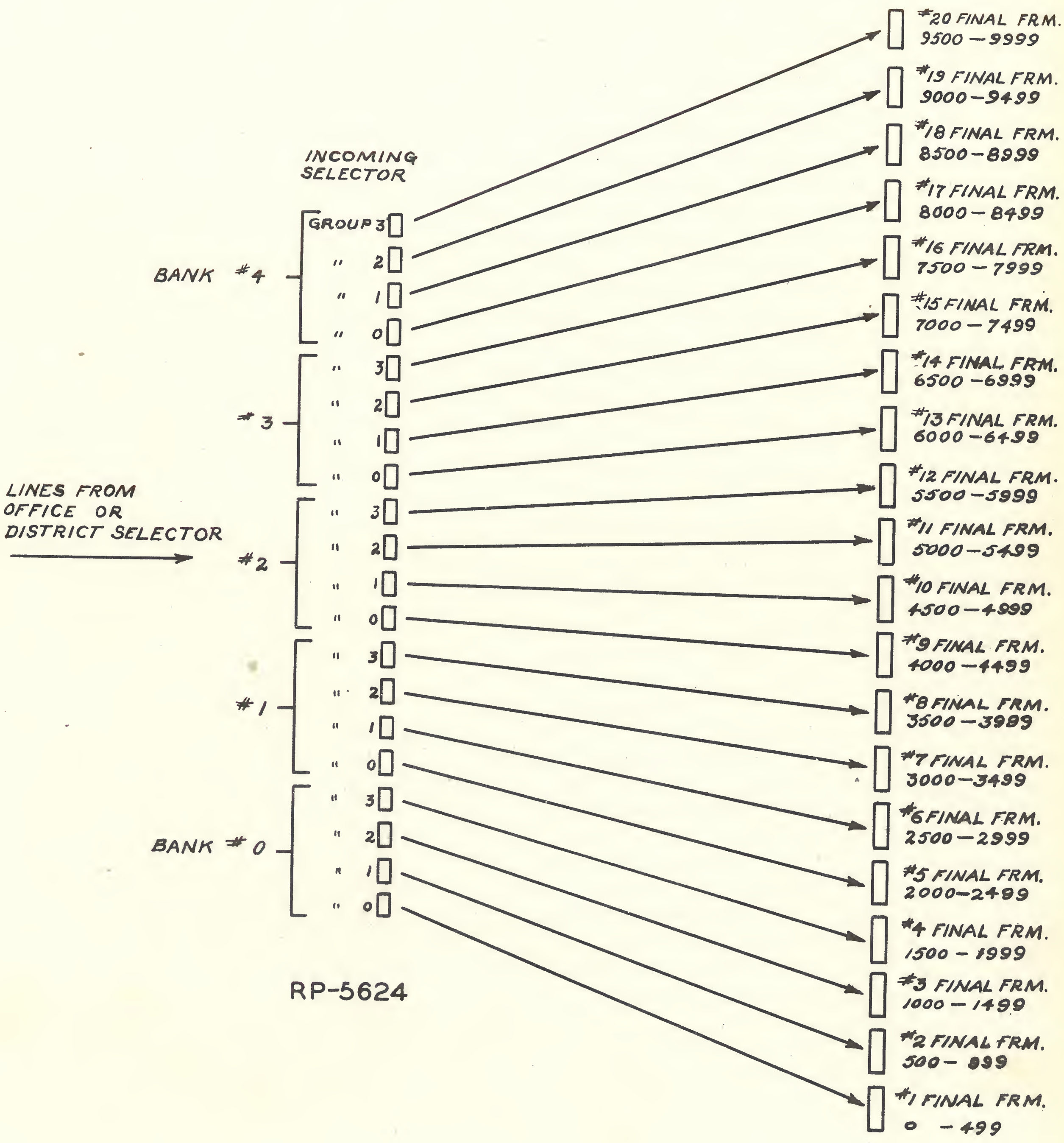

INCOMING SELECTOR
GROUP 3
" 2
" 1
" 0
" 3
" 2
" 1
" 0
" 3
" 2
" 1
" 0
" 3
" 2
" 1
" 0
" 3
" 2
" 1
" 0
BANK #4
#3
#2
#1
BANK #0
LINES FROM OFFICE OR DISTRICT SELECTOR
#20 FINAL FRM. 9500 — 9999
#19 FINAL FRM. 9000 — 9499
#18 FINAL FRM. 8500 — 8999
#17 FINAL FRM. 8000 — 8499
#16 FINAL FRM. 7500 — 7999
#15 FINAL FRM. 7000 — 7499
#14 FINAL FRM. 6500 — 6999
#13 FINAL FRM. 6000 — 6499
#12 FINAL FRM. 5500 — 5999
#11 FINAL FRM. 5000 — 5499
#10 FINAL FRM. 4500 — 4999
#9 FINAL FRM. 4000 — 4499
#8 FINAL FRM. 3500 — 3999
#7 FINAL FRM. 3000 — 3499
#6 FINAL FRM. 2500 — 2999
#5 FINAL FRM. 2000 — 2499
#4 FINAL FRM. 1500 — 1999
#3 FINAL FRM. 1000 — 1499
#2 FINAL FRM. 500 — 999
#1 FINAL FRM. 0 — 499
RP-5624

Fig. 76

CHAPTER VI

Calls from machine switching to manual offices are handled at the manual office on call indicator "B" positions. Fig. 77 shows a diagram of the equipment used to connect such a call to a subscriber in the manual office.

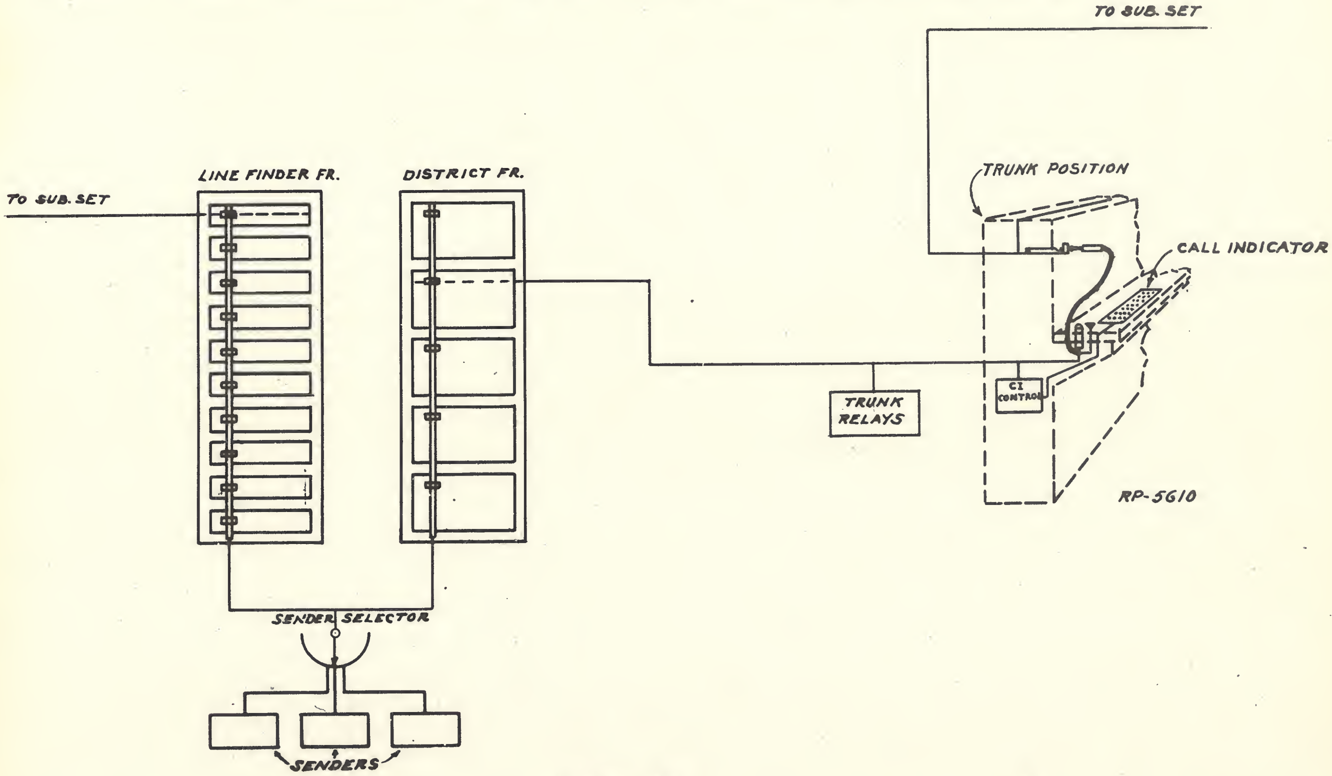


Fig. 77

The call progresses through the district selector in the same manner as described for the machine switching call, but the trunk which it takes up leads to a call indicator "B" position in the manual office selected. The operator is notified that a call has reached her position by the lighting of a lamp associated with the cord in which the incoming trunk terminates. Upon perceiving this signal, she presses a display key associated with that trunk, and thereupon the called subscriber's number is displayed on a bank of numbered lamps located on this operator's keyboard. The operator picks up the plug, tests the called line and, if it is found idle, plugs in, or, if it is found busy, she plugs into a special jack which is arranged to send the intermittent busy tone back to the calling subscriber.

The called subscriber's number is displayed in the following manner. Associated with the operator's position, and with her call indicator, is a group of relays. When the display key is depressed, this group of relays is attached to the trunk. The sender which has meanwhile been waiting on the connection, is thereby given a signal, and sends the number called by means of code pulses which are received by the group of relays. These relays, in turn, light the set of lamps on the call indicator corresponding to the digits of the called number, as shown in Fig. 78 for "13660". The code pulses employed for sending this called number are positive and negative, strong and weak, and are translated by the sender from the decimal dial pulses to this type of pulse to reduce the time required and to simplify the receiving apparatus.

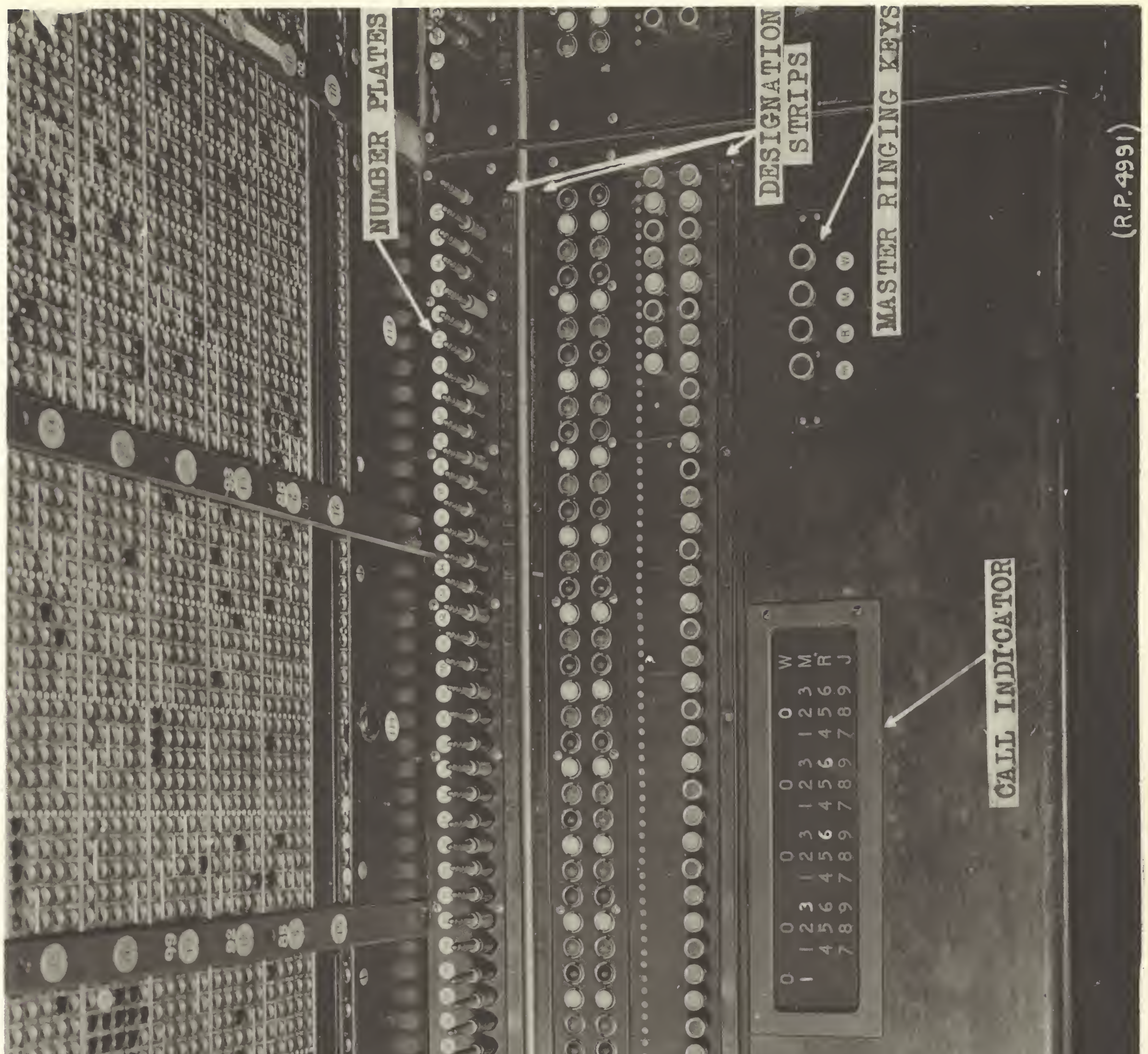

SUBSCRIBER'S MULTIPLE
BUSY BACK JACKS, TRUNKS TO SPECIAL OPERATORS, ETC.
SUPERVISOR'S CORD
TRUNK CORDS
DISCONNECT LAMP
ASSIGNMENT LAMP
TEAMWORK DISPLAY KEY
HOME DISPLAY KEY
NUMBER PLATES
DESIGNATION STRIPS
MASTER RINGING KEYS
CALL INDICATOR
(R.P.4991)

Fig. 78

Similarly, it is also necessary to be able to complete calls from the manual central offices to the machine switching central offices. Calls from manual offices are handled at the machine switching office on cordless "B" positions. Fig. 79 shows a diagram of the equipment used to connect a call originating in a manual office destined for a subscriber in a machine switching office.

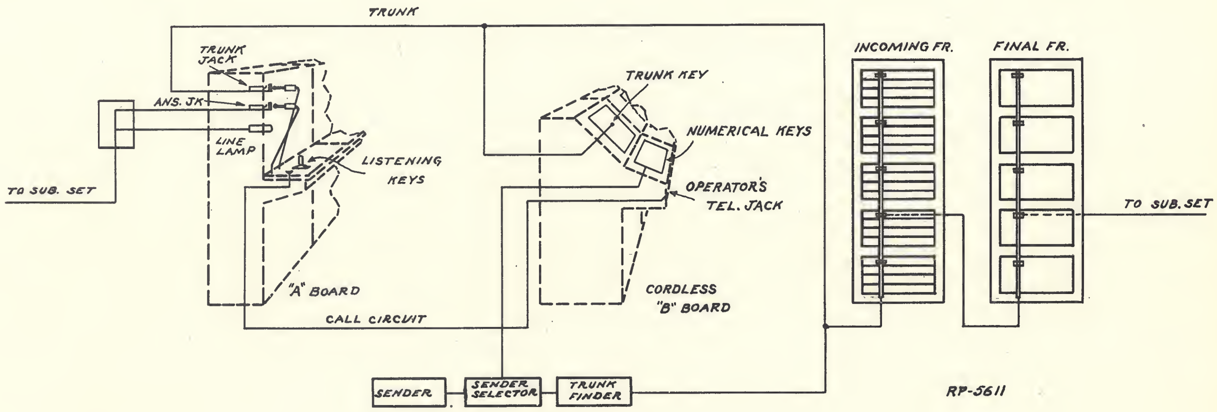


Fig. 79

Such a call is answered by the "A" operator in the manual office in the usual manner. She takes up the call circuit by depressing her call circuit key to the machine switching office desired, passes the called subscriber's number, and receives a trunk assignment in exactly the same manner as if the call were going to another manual office. The cordless "B" operator, upon assigning a trunk, presses the assignment key of that trunk which temporarily attaches her keyboard to a sender and simultaneously to the incoming trunk which she has assigned. As shown in Fig. 79, the incoming trunk terminates on an incoming selector which has access to final selectors on which the called number appears, in the same manner as described before.

The operator now sets up on her numbered keys the number desired, and this information is transmitted immediately to the sender. These keys, which lock mechanically, are released after a fraction of a second by a magnet controlled by the sender and are ready for the next call. The "B" operator's sender now controlls the incoming and final selectors in the same manner as the subscribers' senders, causing the incoming selector to choose an idle trunk to a final selector having access to the desired group of 500 numbers. The final selector reaches its destination in the manner previously described and, as soon as the line is found, the sender is released.

In Fig. 80 are shown a few positions of a cordless "B" board, and in Fig. 81 is shown a "B" sender frame. This sender, as already indicated, performs exactly the same function as the sender for full mechanical or call indicator calls, except that it is not necessary to make an office selection, the only selections required being those of the incoming and final frames.

As a summary, a complete diagram of the three classes of machine switching calls has been shown in Fig. 82. Here we have illustrated a call from one machine switching subscriber to another, a call from a machine switching subscriber to a manual subscriber, and a call from a manual subscriber to a machine switching subscriber.

CHAPTER VI

Fig. 80

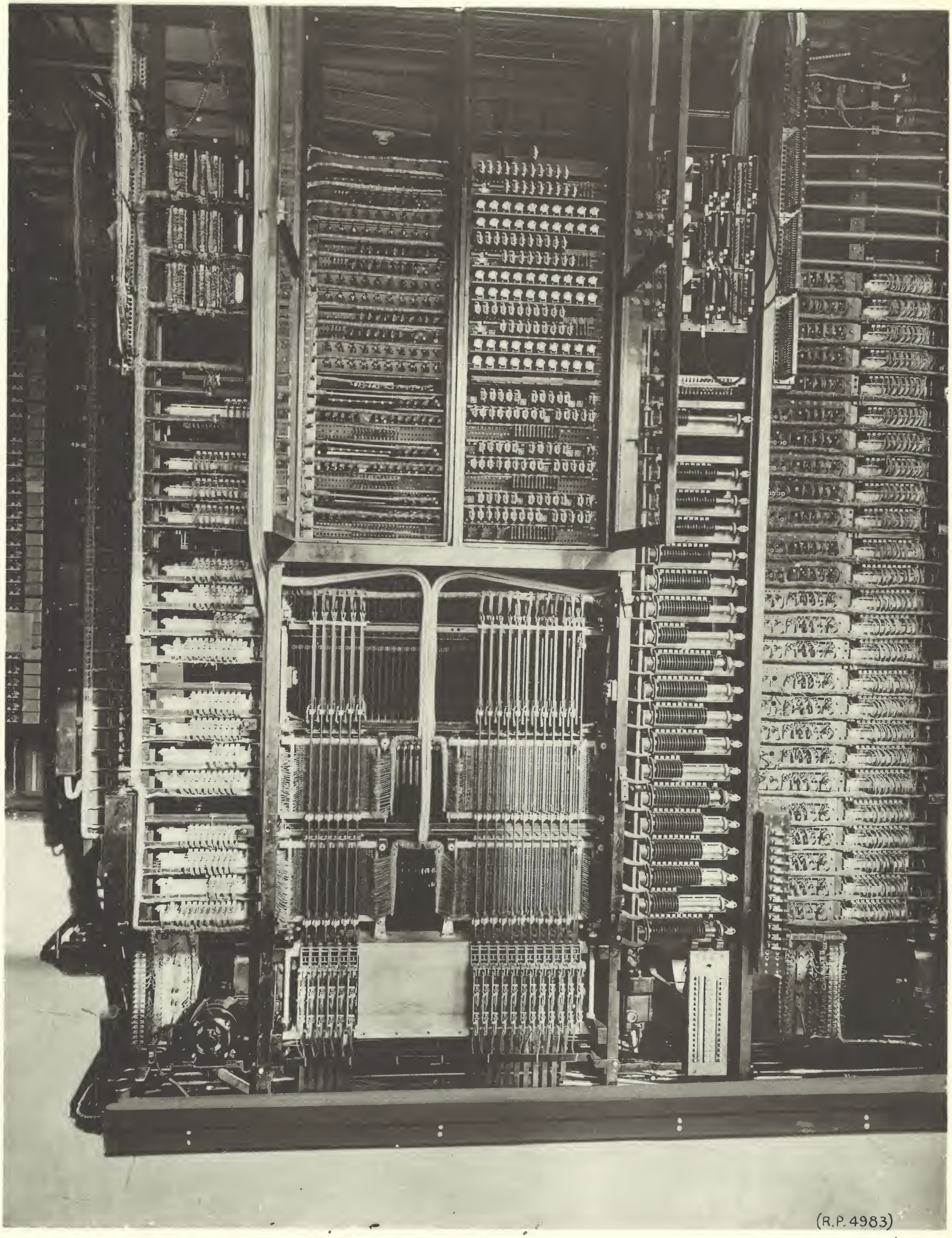


Fig. 81

CHAPTER VI

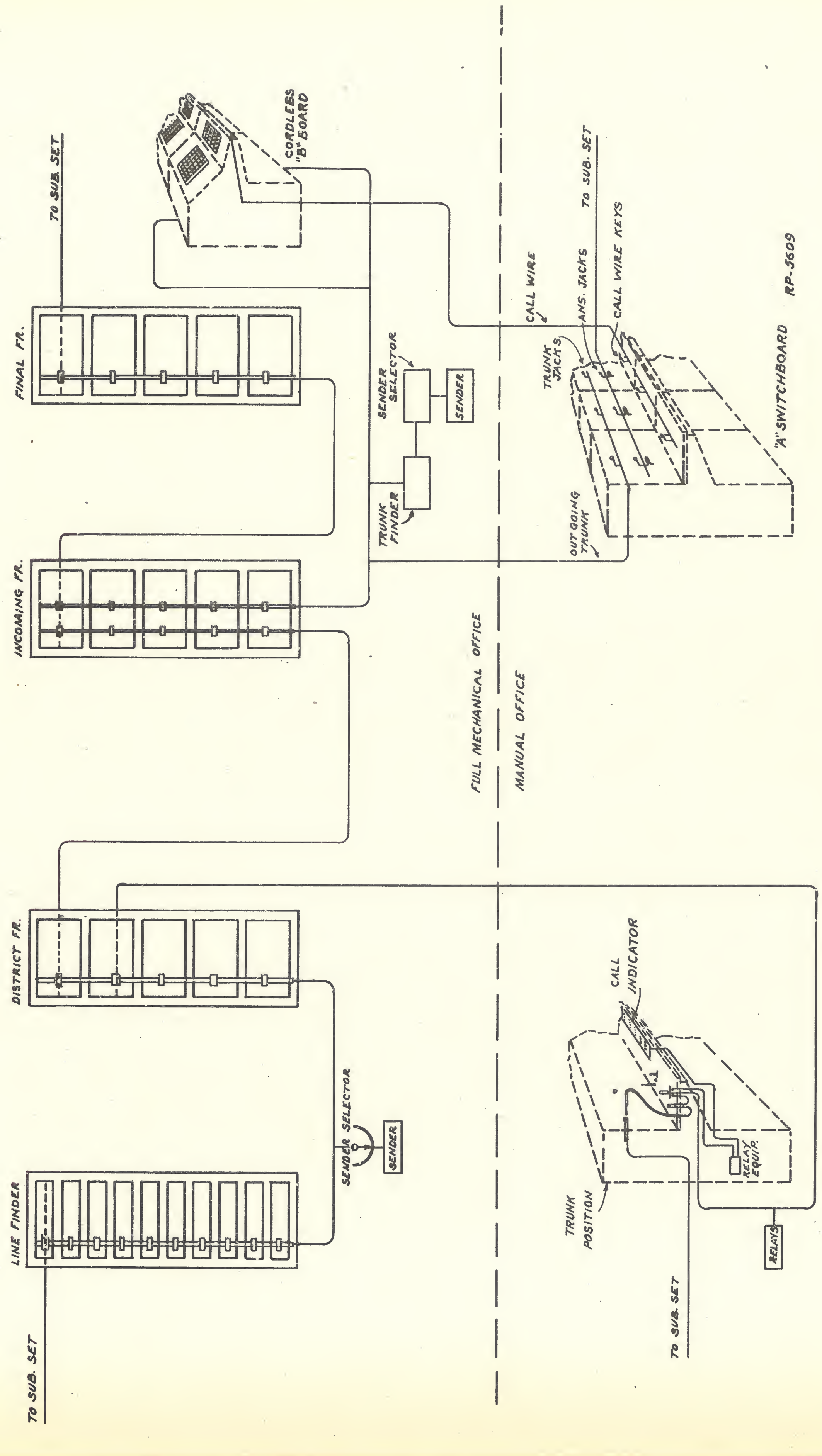


Fig. 82

CHAPTER VII - STEP BY STEP SYSTEM

The step by step system for automatically establishing telephone connections is a direct impulse system. By this is meant that the selecting mechanism is operated directly under the control of the dial impulses instead of indirectly by means of a sender.

The most important piece of apparatus in the system is the selecting switch illustrated in Fig. 83. The bare skeleton of such a switch, sufficient only to illustrate salient points in its mode of operation is shown in Fig. 84. The essential elements of this type of switch are a vertical shaft capable of both vertical and rotary motion; a pawl and ratchet mechanism actuated by a magnet for moving the shaft vertically a step at a time; another pawl and ratchet mechanism actuated by another magnet for rotating the shaft a step at a time; an arm carrying wiper contacts, arranged on the inner surface of a section of a cylinder adapted to be engaged by the wiper contacts on this movable arm.

In the upper left-hand corner of this figure, the vertical magnet shown will, if energized by impulses of current, attract and release its armature, and in doing so, cause the pawl controlled by this magnet to move the shaft of the switch up a step at a time, as many steps as there are impulses of current. The vertical movement of this shaft will carry the wiper arm, attached to the lower end of the shaft, up the same number of steps, and in doing so, will bring the contacts of this wiper arm opposite, but not engaging the corresponding row of stationary contacts in the semi-cylindrical bank. Likewise, through the ratchet cylinder on the intermediate portion of the shaft, the rotary magnet shown in the right-hand portion of this figure will, when energized by a succession of electrical impulses, rotate the shaft a step at a time, as many steps as there are impulses. This will cause the contacts of the wiper arm to move over the successive contacts in the row opposite to which the wiper had been carried in its vertical motion.

In the lower left-hand corner of this figure, there is shown a pair of keys, either one of which when operated, will complete the circuit of the magnet to which it is connected, this circuit including a common battery. This pair of keys may be taken as representing the call-transmitting apparatus at the subscriber's station, and the two wires extending therefrom may be taken as representing the line wires connecting that subscriber's station to the central office; but these two wires must not be thought of as the actual representation of the subscriber's station calling apparatus or the subscriber's line, since their counterparts are not found in the system as it really exists. Accuracy has been sacrificed for ease in setting forth a feature of operation.

Referring again to Fig. 84, it will be seen that the bank contacts consist of ten rows or levels, each having ten pairs of contacts.

For the sake of simplicity, let us assume that the exchange under consideration has one hundred subscribers, and that each pair of bank contacts represents the terminals of one subscriber's line. The simplest kind of automatic

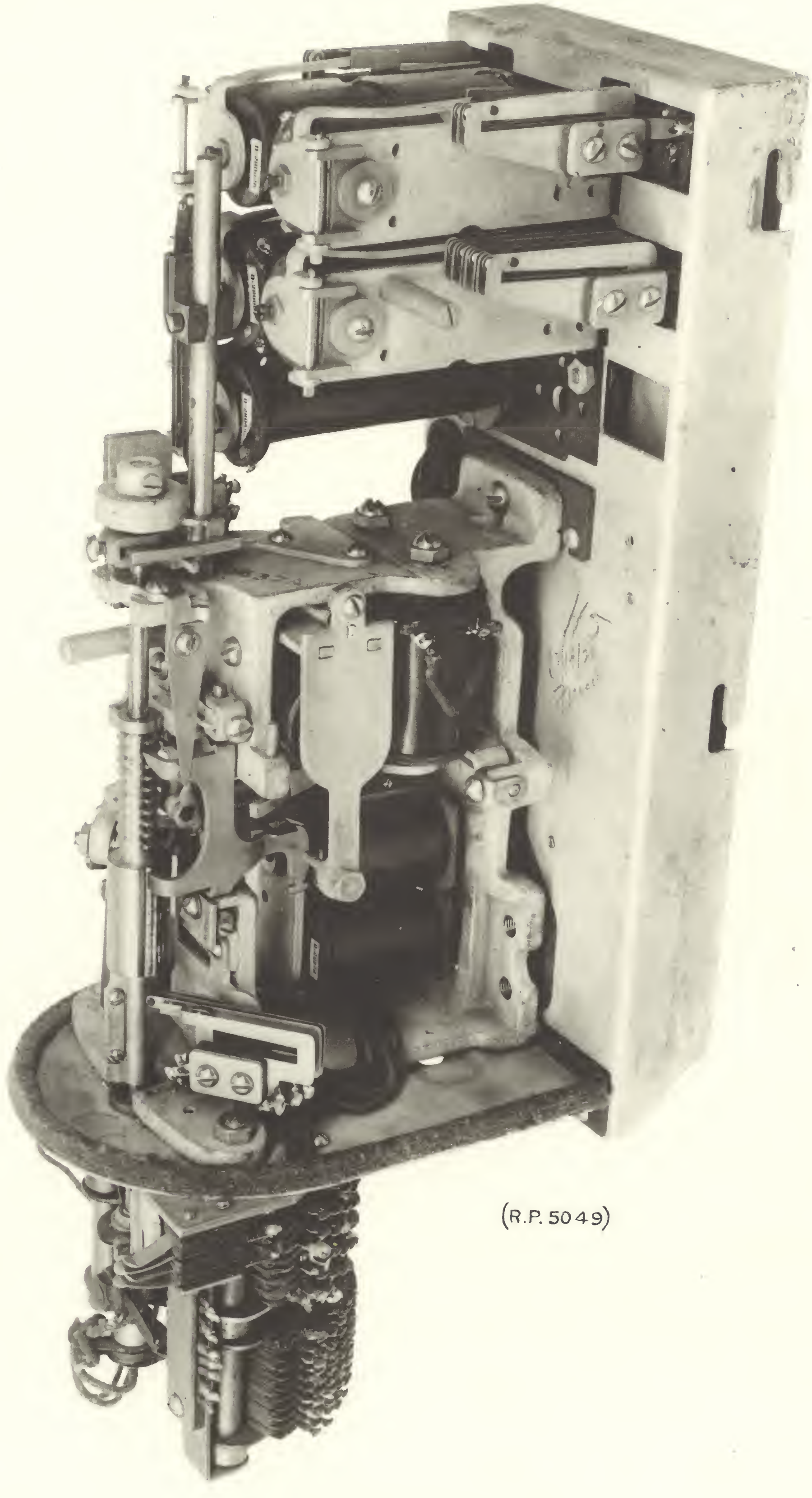

(R.P. 5049)

Fig. 83

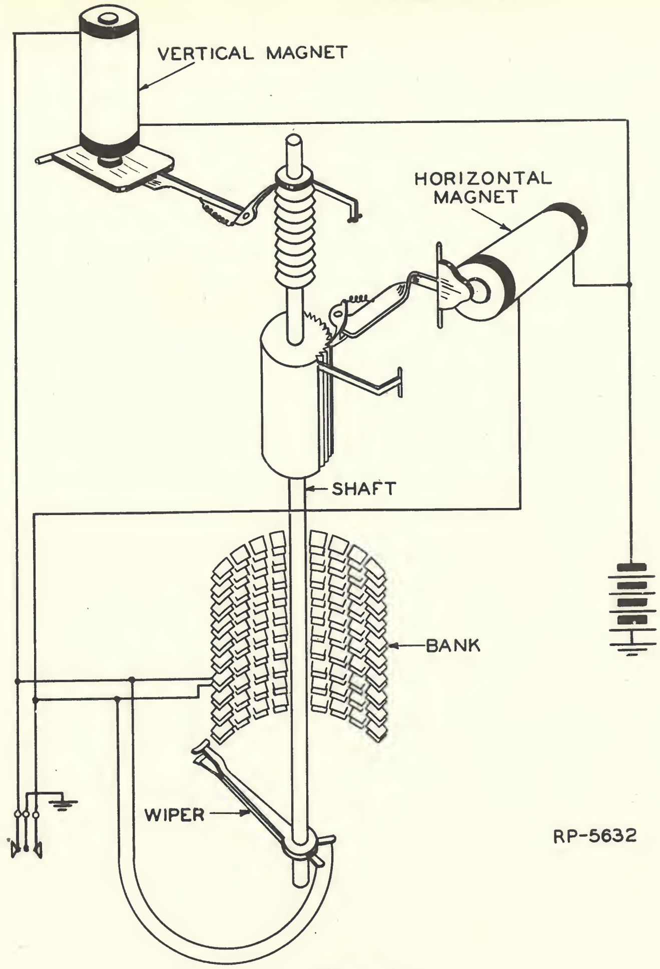


Fig. 84

exchange is one where each subscriber's line terminates in a selecting switch, and where every switch has access to a multiple of every line through the semi-cylindrical banks.

Fig. 85 shows a bank of contacts as it would appear if the bank were bent back so that all contacts were in the same plane. The levels are numbered from 1 to 10 from the bottom up, and the contacts are numbered from left to right. Number 10 is indicated by "0". The tens digit of a number called indicates the level on the bank where the multiple of that number appears. The units digit of the number indicates the contact to which that number is multipled. Thus, number 57 is connected to contact 7 of level 5, or in the order of dialing up five and around seven.

The upper bank in this diagram is for the 3rd wire or sleeve connection. This was omitted in the skeleton diagram of the switch for the sake of simplicity but in actual practice each switch always has 2 sets of wipers, one for the tip and ring and the other for the sleeve connection. These are mounted on the same shaft and move up and around together.

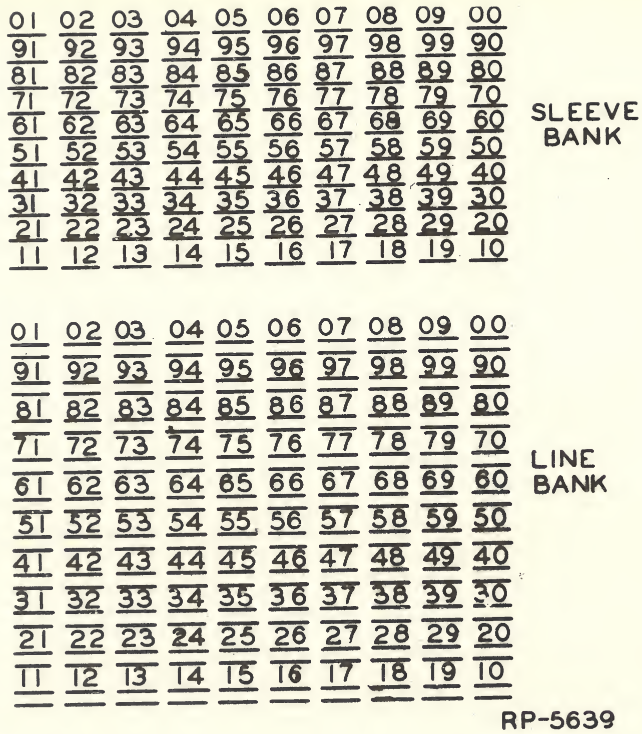


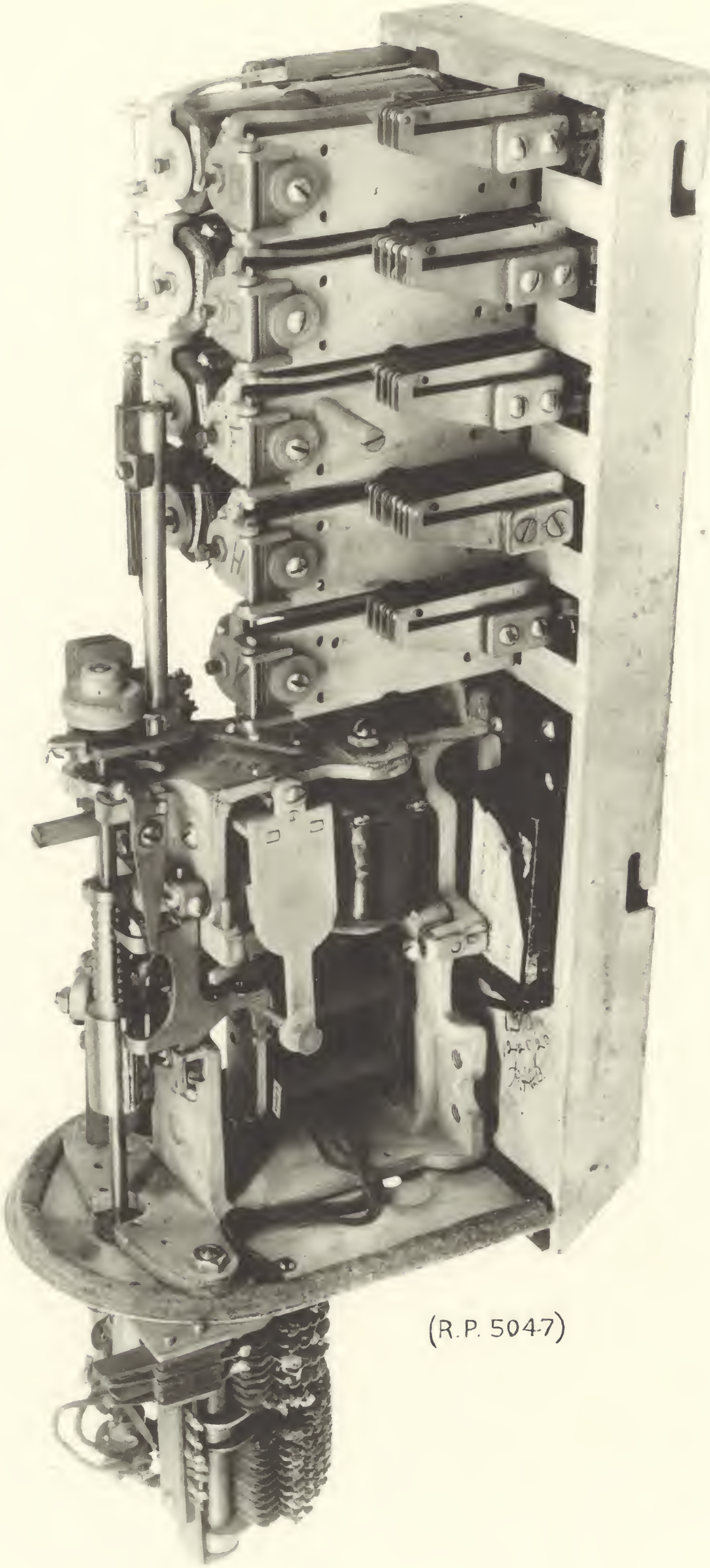
Fig. 85

Referring again to Fig. 84, let us assume that the subscriber operates the keys at the lower left-hand corner in place of a calling dial. Let us further suppose that the subscriber wishes to call number 74. It may be seen that two wires from the subscriber's station are connected to contact No. 1 of the fourth level. This indicates that the number of the calling station is 41. Also, the switch shown is for the exclusive use of No. 41, each of the other stations having a switch for their individual use.

In calling No. 74, the key in the vertical magnet circuit is pressed seven times. This sends seven impulses to the magnet, and steps the shaft up so that the wiper will stop opposite the 7th level. The key in the rotary magnet circuit is now pressed four times, and the wiper is stepped around to the 4th pair of contacts of the 7th level. This pair of contacts is connected to station No. 74. In the same manner, number 74 may be called from any other switch in this 100-line exchange. Each pair of contacts in one bank is multipled to the corresponding contacts throughout all the switches.

This type of selecting switch, whose banks contain the multiples of the subscriber's lines, is called the connector switch. In actual practice, each connector is connected to a trunk from the selector banks instead of to an individual subscriber's line. The assembled connector switch may be seen in Fig. 86.

The selector, like the connector, is of the "up and around" type of switch, and the two are very much alike in appearance and operation. However, one of the greatest outstanding differences between them is that while both require dial impulses for the vertical movement of the shafts, the shaft of the selector rotates automatically.



(R.P. 5047)

Fig. 86

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All the contacts of selector banks are connected to trunk lines to other groups of switches; the ten trunks of the first level will go to one group of switches, those of the second level to the second group of switches, and so on. At the end of the vertical motion, the wipers will pass to the first contacts of the level opposite, automatically. If the first trunk is busy, the wipers will pass over its contacts, and so on, until it reaches an idle trunk, where it stops. Selectors are divided into several classes as first, second, third or fourth selectors, but all of these are practically alike. The different classes are used according to the number of lines in a system. A frame of selector switches is shown in Fig. 87.

If every subscriber's line terminated in an "up and around" type of switch, not only the cost of an office would be increased very much, but also a much greater space would be required. For this reason, each subscriber's line terminates individually on what is known as the plunger type non-numerical line switch shown mounted on the frame in Fig. 88. These switches are arranged in upright sections of two hundred switches - one hundred on each side. The switches of each upright section are divided into groups of different sizes, and ten outgoing trunk lines are provided for each group. The groups in different cases consist of 25, 50, 75 or 100, according to the amount of traffic they are required to handle.

As may be seen from Fig. 89, each line switch is equipped with a plunger arm, the plunger of which is in position over the bank contacts of ten trunks. The plungers are kept in alignment over the contacts of an idle trunk by a shaft which is in turn operated by a master switch. When the receiver of a subscriber's line in any group is removed from the hook, the switch of that line will operate, and its plunger will plunge into the bank, and extend the connection to the next switch. The moment the line switch plunges, the master switch will operate and move the plungers of all the idle line switches so that they will stop over the next idle trunk. The operated switch, however, will remain plunged in the bank, and will be picked up after it has been released when the shaft passes over that trunk again. The details of a line switch are shown in Fig. 90, and a master switch in Fig. 91.

In Fig. 92 is illustrated a trunking scheme for an office having only 100 lines. Each telephone is connected directly to a connector and the capacity of such a system is limited to 100 lines, or the capacity of one bank. Each telephone number has two digits. It will be observed that 11 is the first contact of the first row, and that 10 is the tenth contact of the first row. The reason for this is that when the dial is turned from "0", 10 impulses are sent out, therefore, dialing the digit 1 would step the connector wipers opposite the first row of contacts, and the dialing the "0" would cause them to travel 10 contacts in a horizontal direction, thus coming to rest on the 10th set of contacts in the first level or on the terminals of telephone number 10.

In Fig. 93 is shown a trunking scheme to provide for 1000 lines. By the enlargement of the system from 100 to 1000 lines, it is obvious that some means of trunking must be provided to select a connector in the proper 100 group.

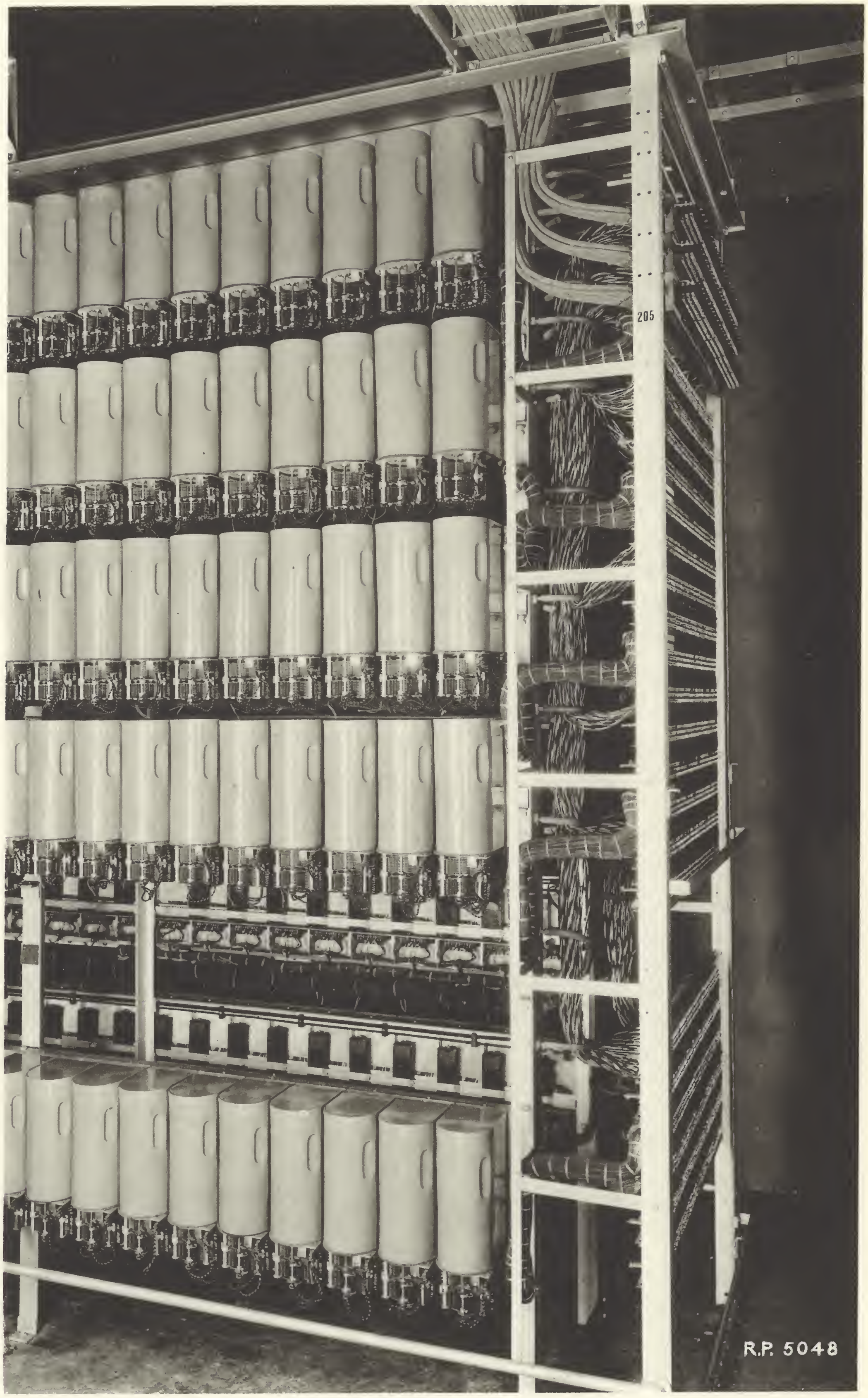

Fig. 87

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Instead of each telephone being connected to a connector switch as in the 100 line system, the telephones are now connected to selector switches. The selector selects a connector in the proper hundreds group and the connector the tens and units as before. This makes possible the enlargement of the system from 100 to 1000 lines.

In a 1000 line system of this kind, there would be 1000 first selectors. The bank contacts of these selectors would be multipled together, and from each row or level of contacts, there would be trunks to the connectors of each 100 group of subscribers' lines.

For convenience we will consider these trunks to be on a straight 10 percent basis, that is, 10 trunks from each level of contacts of the first selector banks to 10 connectors in each 100 line group.

Each telephone number of a 1000 line system has 3 digits. It will be observed that to change a 100 into a 1000 line system it is only necessary to terminate the lines on selectors instead of connectors and to provide the additional connector groups.

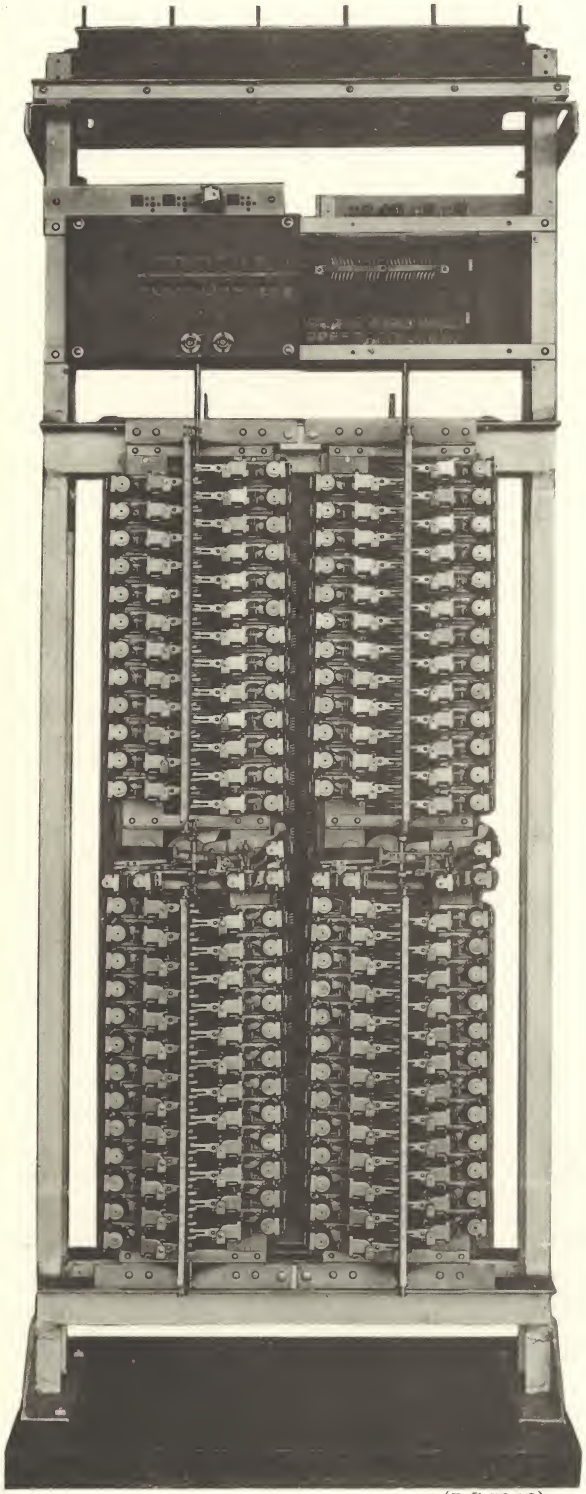


Fig. 88

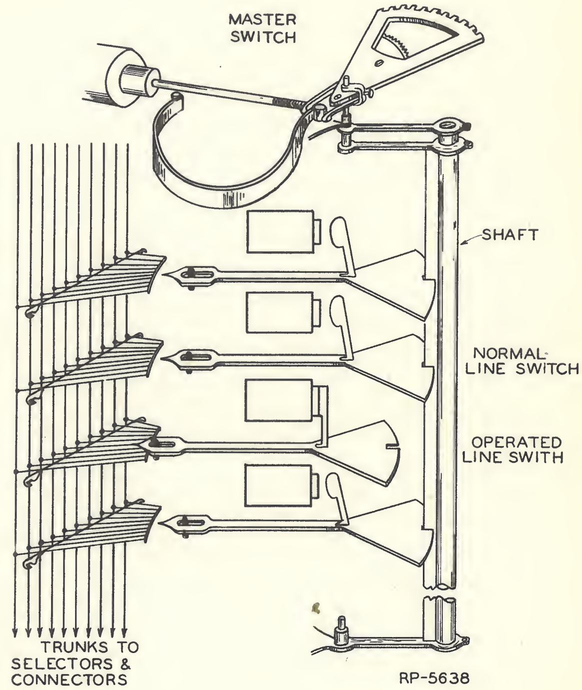


Fig. 89

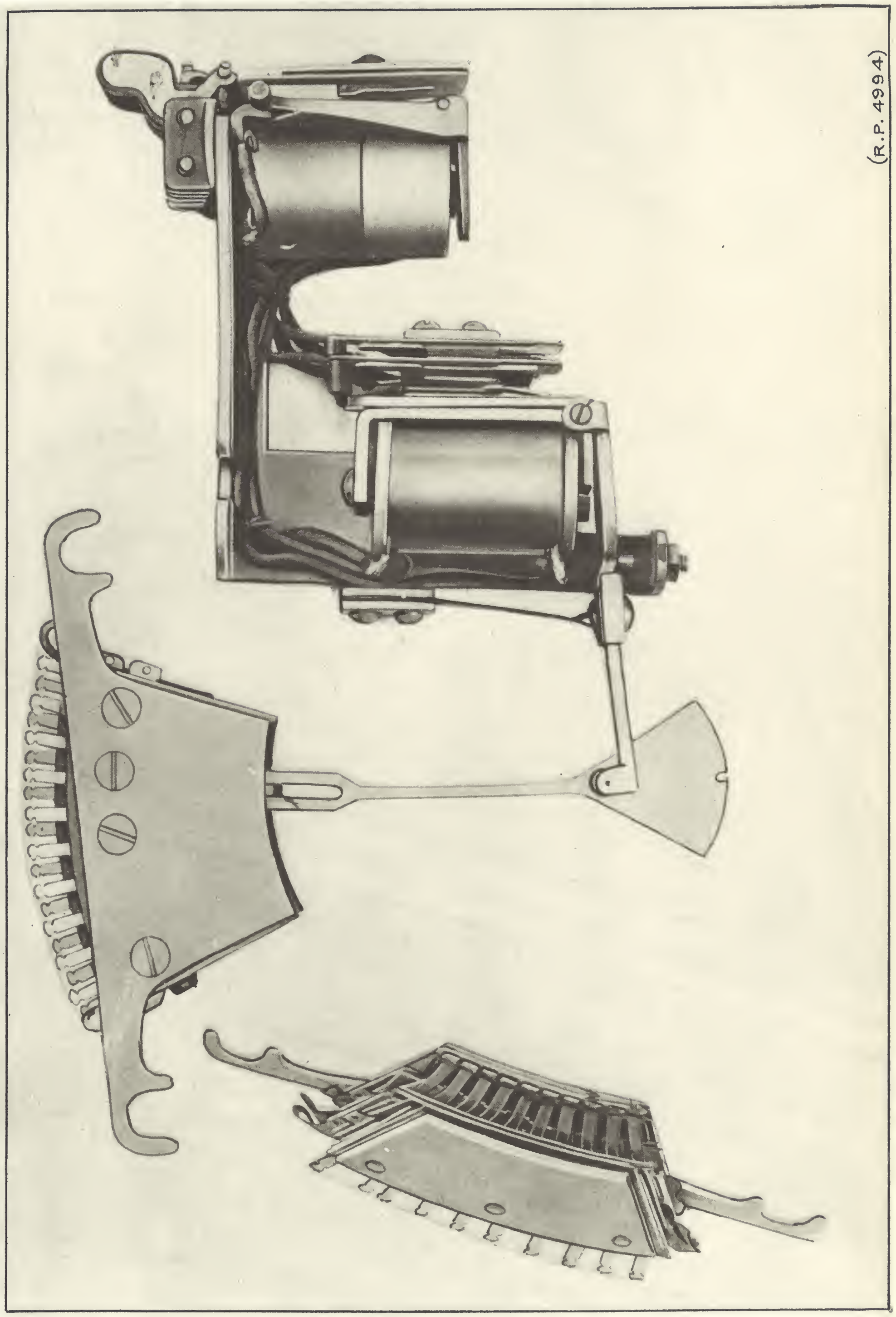
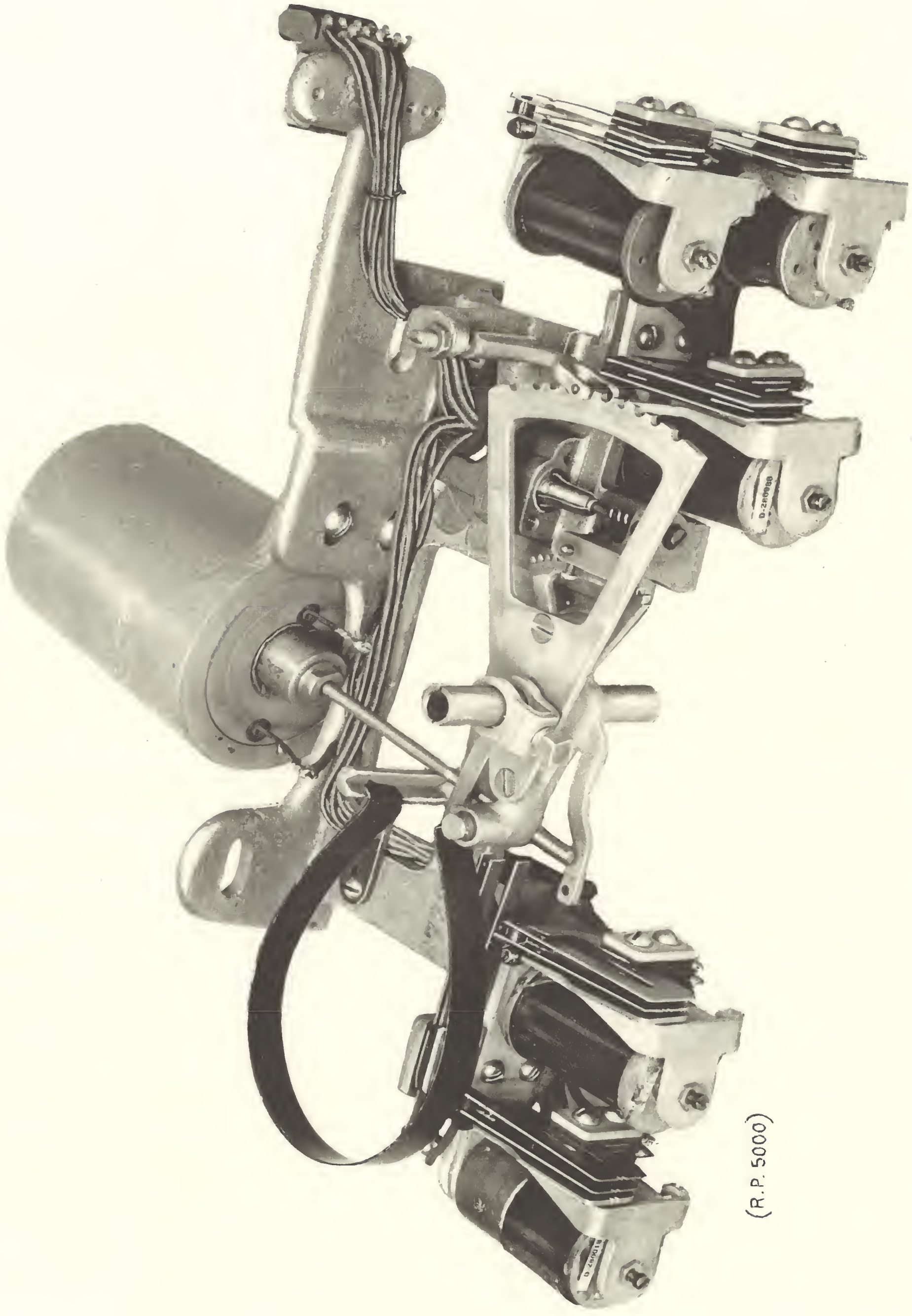


Fig. 90



(R.P. 5000)

Fig. 91

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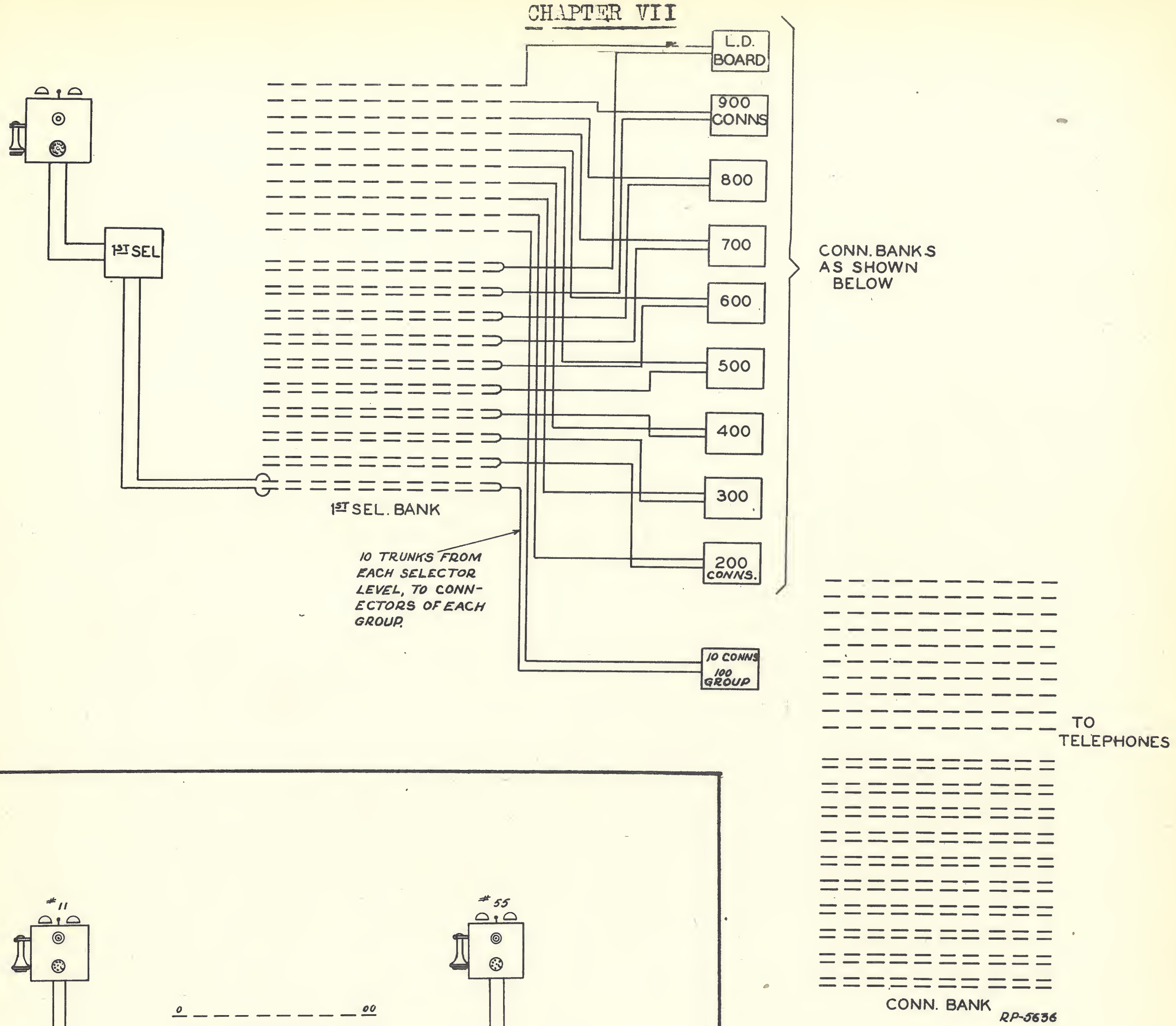

Fig. 93

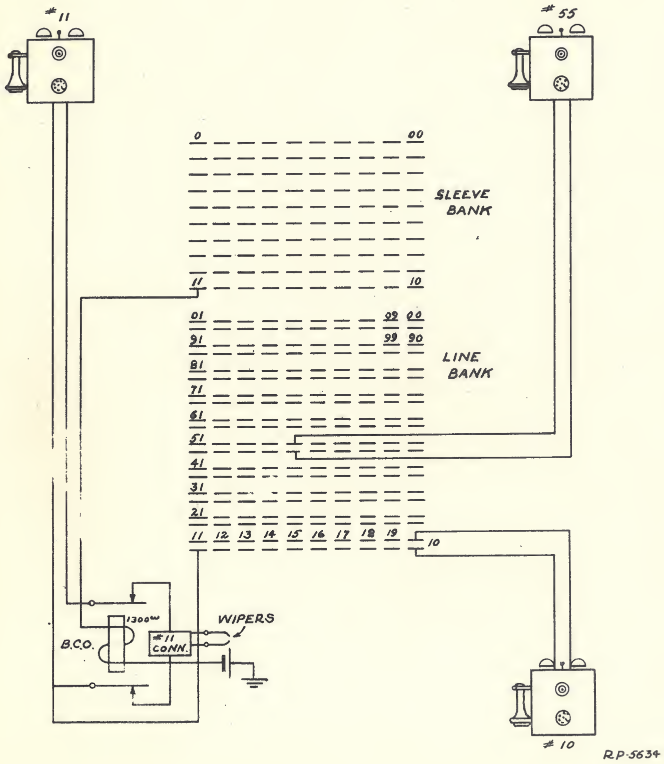

Fig. 92

When telephone number 125 is dialed, the connection is completed as follows: Dialing the digit "1" elevates the wipers of the calling subscriber's first selector up to the first level. The selector then automatically rotates its wipers over the contacts of that level until a trunk to an idle connector of the 100 group is found. Dialing the digit "2" elevates the wipers of the connector to the second level. The digit 5 is now dialed. This extends the connector wipers to the fifth set of contacts of the second row (or No. 25). This connects the calling party's telephone with the called party's telephone No. 125.

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To increase the number of telephones from 1000 to 10,000 it is only necessary to introduce 2nd selectors between the 1st selectors and connectors. A diagram of the trunking arrangement of a 10,000 line system is shown in Fig.94.

In a system of this size the first selector selects the desired thousand, the second selector the desired hundred, and the connector the tens and units, or, in other words, the desired line itself.

Instead of the trunks from the levels of the first selectors being connected direct to connectors as was the case in the 1000 line system, they are, in the 10,000 line system, connected to second selectors. The bank contacts of the second selectors are connected to the connectors. Each level of the first selectors represents a capacity of 1000 lines, In the 1000 line system each first selector level represents a capacity of 100 lines. In other words, for each group of selectors (firsts, seconds, etc.), added, the capacity of the exchange (in lines) is multipled by ten. Each telephone number in a 10,000 line system has 4 digits.

Each exchange is provided with special services, such as Long Distance, Information, Complaint, Wire Chief, etc., where an operator is in attendance, Means for for connecting to these is shown in Fig. 94. Dialing "O" connects to Long Distance; 912, Information; 913, Complaint, etc.

In order to reduce the number of selectors, the lineswitch was introduced. The lineswitch is a non-numerical switch attached to each subscriber's line, and serves to connect the line to a trunk leading to an idle connector in a 100 line system or an idle first selector in a larger system.

The lineswitch consists of a line relay and a cut-off relay, such as is used in common battery manual practice, and a plunger which can be drawn into a set of bank contacts, operating them and thus connecting the subscriber's line to a trunk leading to a selector switch. In other words, it makes possible the use of a small group of trunks by a larger group of subscribers' lines.

In Fig. 95 is shown the trunking arrangement of a 10,000 line system using a lineswitch for each telephone. This lineswitch merely extends the subscriber's line to the first selector and it will be observed that the first digit from the dial operates the first selector just as it did before the lineswitch was introduced in the system. The normal wires are a multiple of the subscribers' lines from the lineswitches to the connector banks and are comparable with the multiple between the answering jacks and subscribers' multiple on manual multiple switchboard.

In Fig. 96 is shown a diagram comparing step by step with manual and panel equipments. Each subscriber's line is connected to a lineswitch which, as already mentioned, plunges in, making contact with an idle trunk when the subscriber removes the receiver from the switchhook. This extends the line to a selector. The first digit dialed moves this selector to the level corresponding with the number of impulses transmitted by the dial. The switch then automatically steps around until it selects the first idle trunk. As the next digit is dialed this performance is repeated in the same manner and so on, until the connector is reached. The tens and units selections are made at the connector, the tens

CHAPTER VII

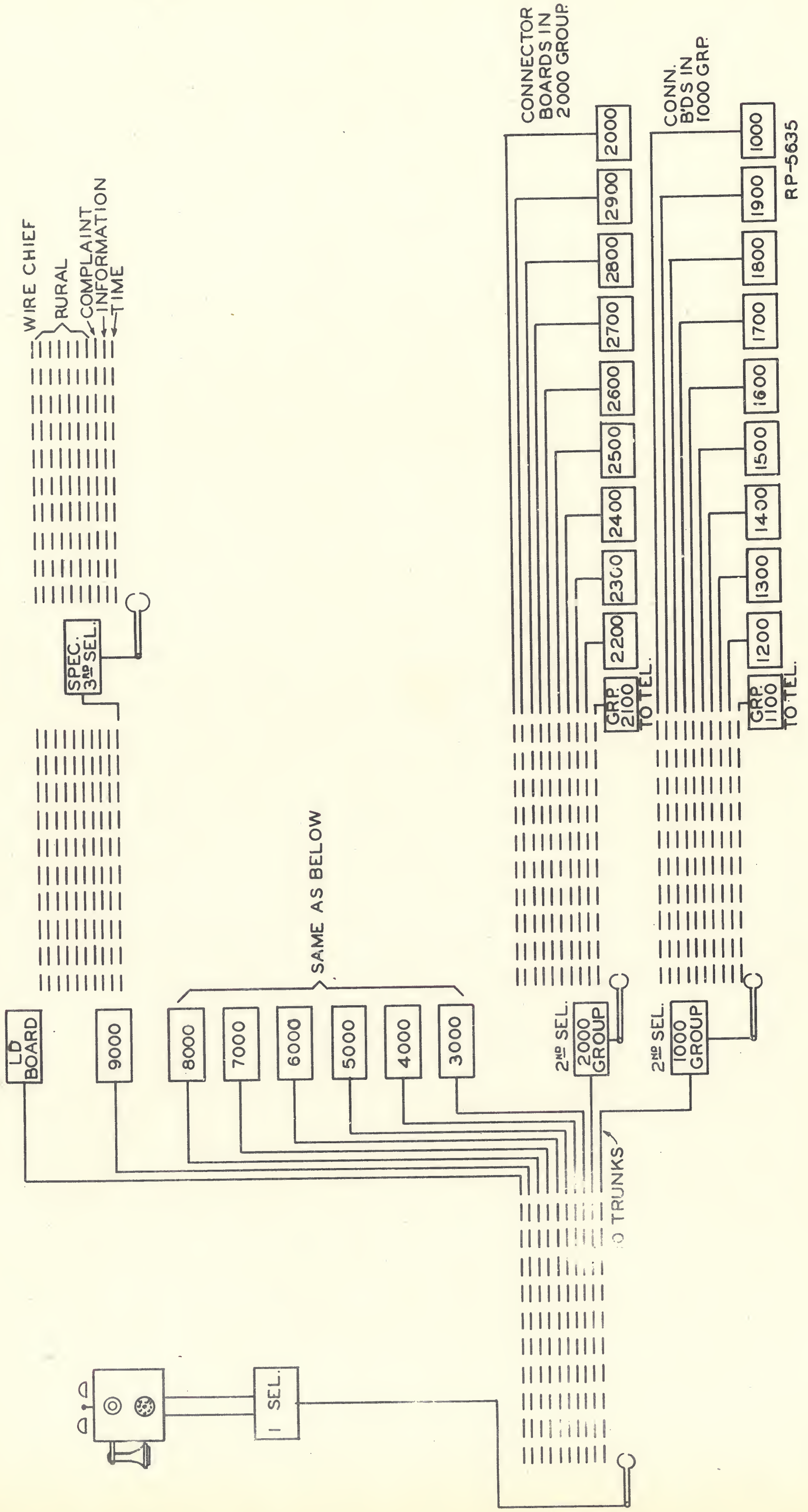


Fig. 94

CHAPTER VII

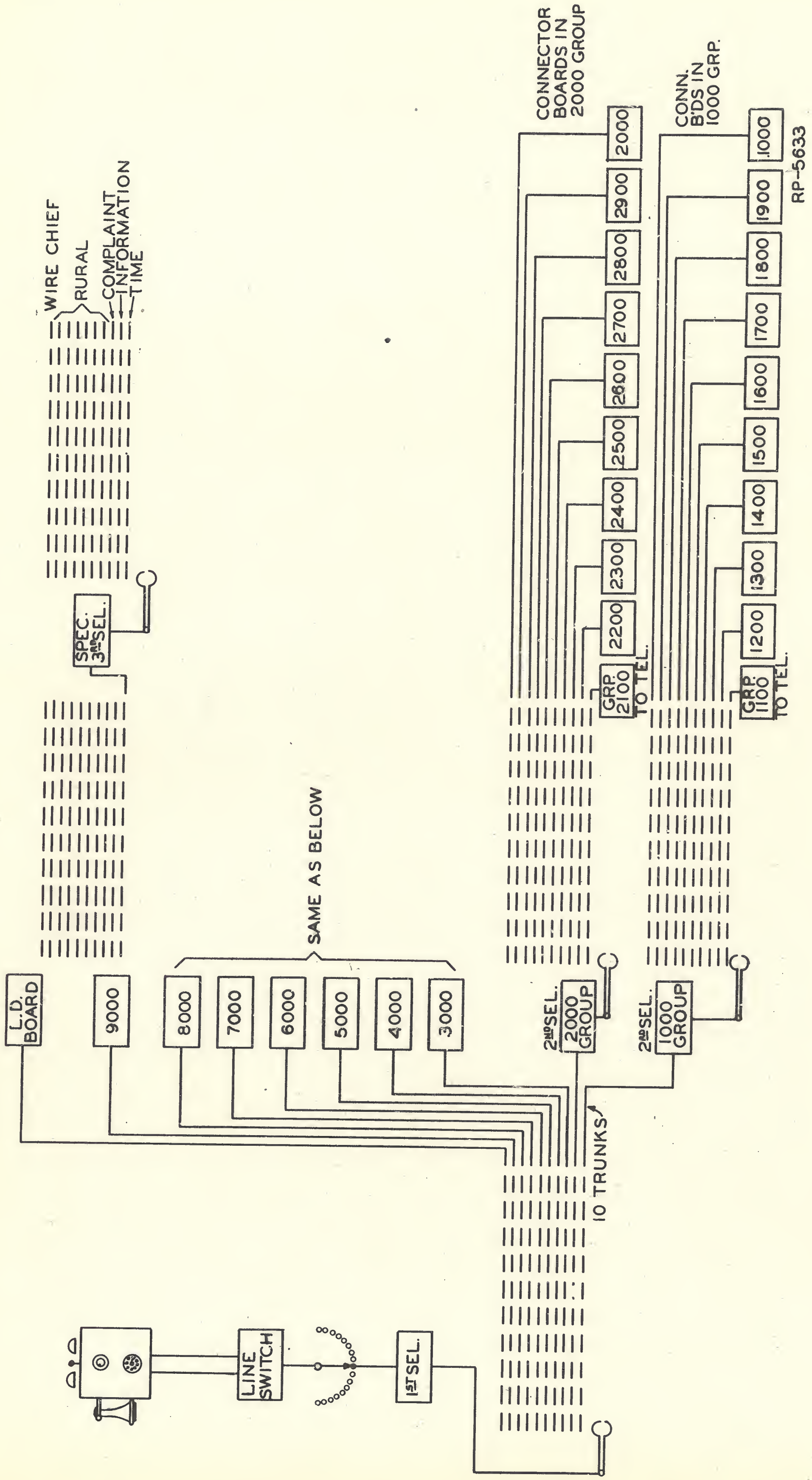


Fig. 95

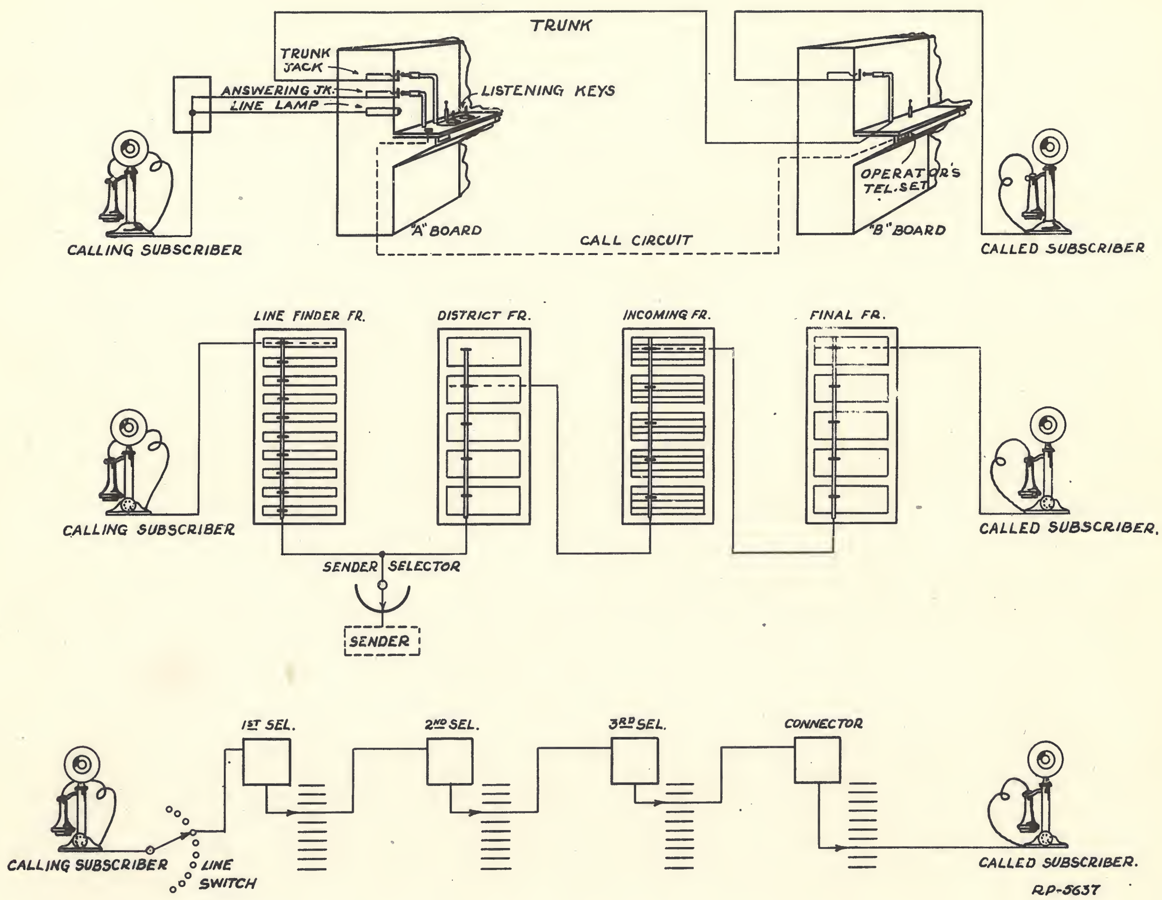


Fig. 96

digit selecting the proper level and the units the proper line. There is not the close similarity of functions between step by step and manual equipments that there is between panel and manual equipments, although the lineswitch duplicates roughly the operation of the "A" board in extending the line to a trunk. From that point on, the operation simulates the work of the "B" operator except that it is necessary to make several selections, in order to arrive at the particular group in which the subscriber's line is located. The trunking arrangement used in this system being on a decimal basis, requires a selector for each digit in the number except for the connector where the tens and units selections are made.

CHAPTER VIII - LONG DISTANCE TELEPHONE EQUIPMENT

In order to render telephone service between distant points, it is necessary to provide special equipment. Service of this kind is known as toll service because an extra charge is made beyond the regular local service rates. Certain classes of toll calls may be made from an "A" board to a "B" board, similar to an ordinary inter-office local call, in which case it is called an "A-B" toll call. Calls between separate cities or localities are known as "long distance" toll calls.

It is the equipment required for taking care of the long distance calls that we are particularly interested in. The switchboards for this service are usually in a separate central office known as a toll office, but are similar to those used for local service and are designated according to the use to which they are put in establishing long distance connections. The first operation that takes place when a subscriber asks for long distance is to connect the subscriber to a recording board in the toll office where an operator records all the information necessary in order to enable other operators to complete the connection. This connection is illustrated in Fig. 97.

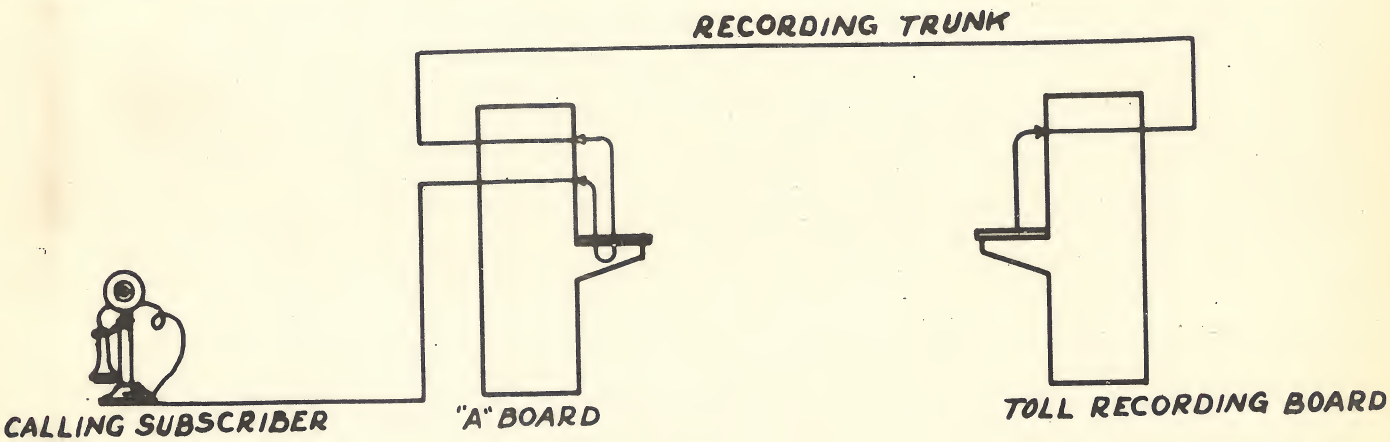


Fig. 97

After this record has been completed the subscriber is advised that he will be called back when the connection is ready. The ticket is then sent to an outward toll board where the operator proceeds to get in touch with the toll office in the town where the called party is located. The call from the operator at the outward board is received at an inward board in the distant toll office where the operator obtains the necessary information with regard to the party desired and then establishes the connection to the called party over a toll switching trunk which is similar to an incoming trunk except that it is arranged to function with a toll cord instead of with an "A" cord. When the party has been located, she notifies the outward operator at the distant toll office who in turn calls back the party who originated the call, over a toll switching trunk in a similar manner to the way in which the connection to the called party was established.

In Fig. 98 is shown the complete equipment for establishing a call, and in Fig. 99 the circuit over which conversation takes place. In cases where there

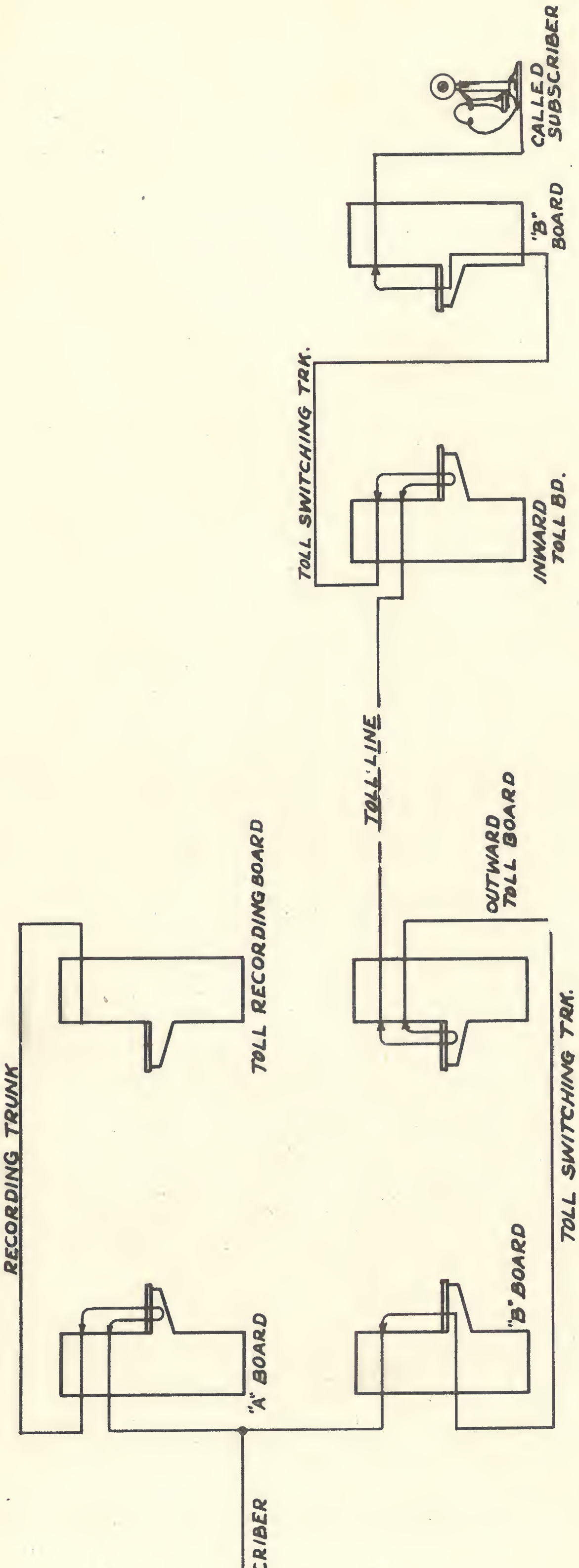


FIG. 98

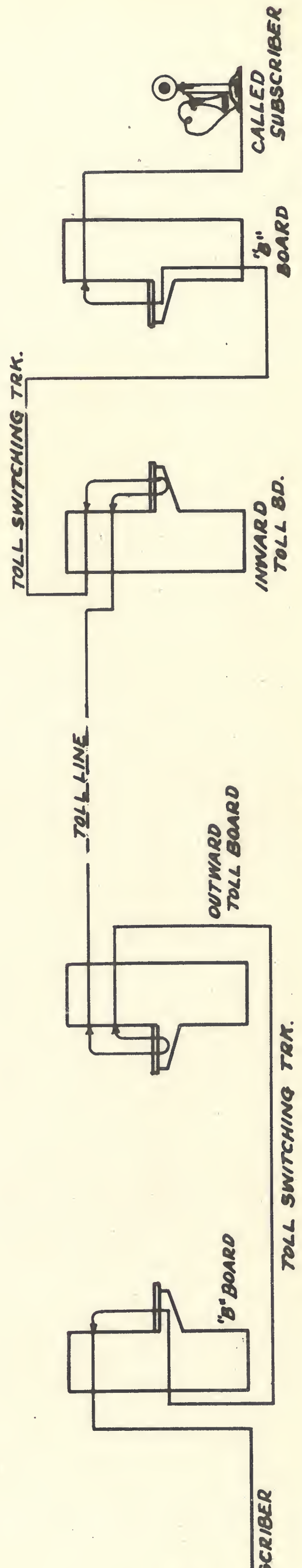


FIG. 99

RP-5640

are no direct toll lines to the town in which the desired party is located, it is necessary to establish a connection through some other town. The connection at the intermediate point is set up at what is known as a "through" position. The equipment for this position is essentially the same as that used in an outward or an inward position.

A recording board is shown in Fig. 100 and an outward board in Fig. 101.

The construction and maintenance of toll lines is necessarily a much more expensive proposition than that of local lines. This is due to the fact that longer distances are covered often through country which is sparsely populated and not easily reached by construction and maintenance crews. It is, therefore, imperative that all toll lines be operated at the maximum capacity and efficiency. A number of methods are in use which increase the number of messages per pair of wires that may be sent over a telephone line.

One of the earliest methods of providing additional telephone circuits on existing lines is known as the "phantom" circuit. By this means 3 telephone circuits are provided over two pairs of wires. In order to understand the operation of these circuits we must understand the principle of the division of current in parallel circuits. In Fig. 102 is shown a simple illustration of a parallel circuit. It will be noted that the current divides, part going through each of the two wires of the parallel circuit. If the resistance of these two wires is equal, the amount of current flowing through each of the two wires will be equal.

The next step in building up this scheme is shown in Fig. 103 which, from a circuit standpoint, is exactly like Fig. 102, except that two coils have been inserted in each end of the circuit. By making these coils one pair of the windings of a repeating coil, we have established the fundamental circuit of the phantom. This is shown in Fig. 104, the other two windings of the repeating coils having been added. A voice current in one of the repeating coil windings will be induced in the winding connected to the line and reproduced in the local circuit by the other repeating coil.

We are now ready to consider a complete phantom circuit as shown in Fig. 105. The two pairs of wires used for the regular lines are the "physical" circuits, "L-1" and "L-2". The dotted arrows indicate the path of the current in the phantom circuit and the solid arrows the path of the current in the side circuit. Voice currents in the side or physical telephone circuit flow in opposite directions in the two line wires while the voice currents due to the phantom circuit flow in the same direction in these wires. Since the two wires of the phantom circuits are connected to the centers of the line windings of the repeating coils, the current divides, half going over one side of the line and the other half over the other, so that the current flowing in one winding is neutralized by the current flowing in the other winding, consequently there is no current induced in the winding of the repeating coils connected to the telephone set of the physical circuit.

In addition to this phantom arrangement of two telephone lines, it is also possible to utilize the same wires for telegraphic circuits. The most common scheme is what is known as the "composite" circuit which utilizes condensers and retardation coils for separating the high frequency voice currents from the low

Fig. 100

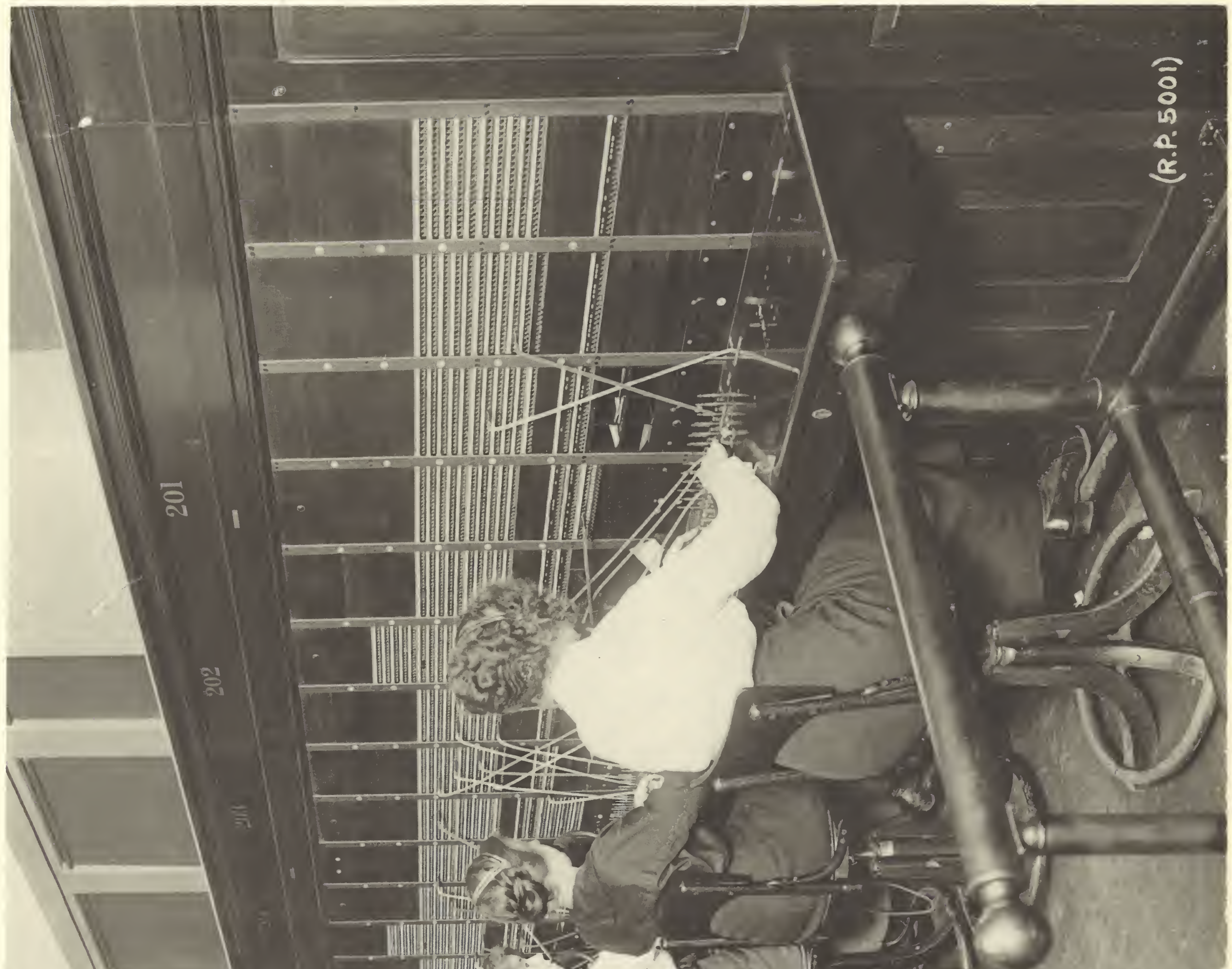


Fig. 101.

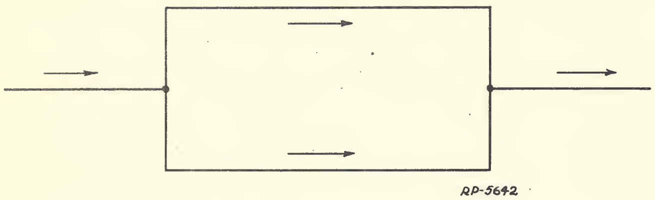


Fig. 102

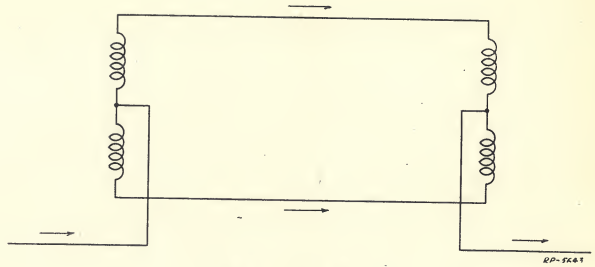


Fig. 103

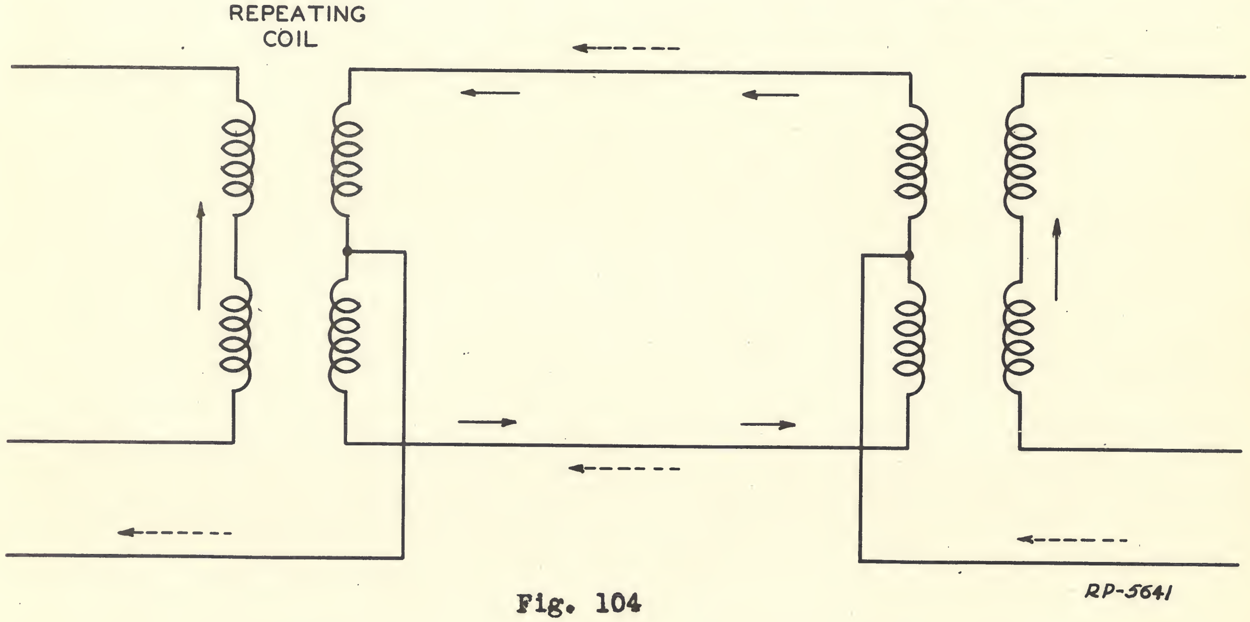


Fig. 104

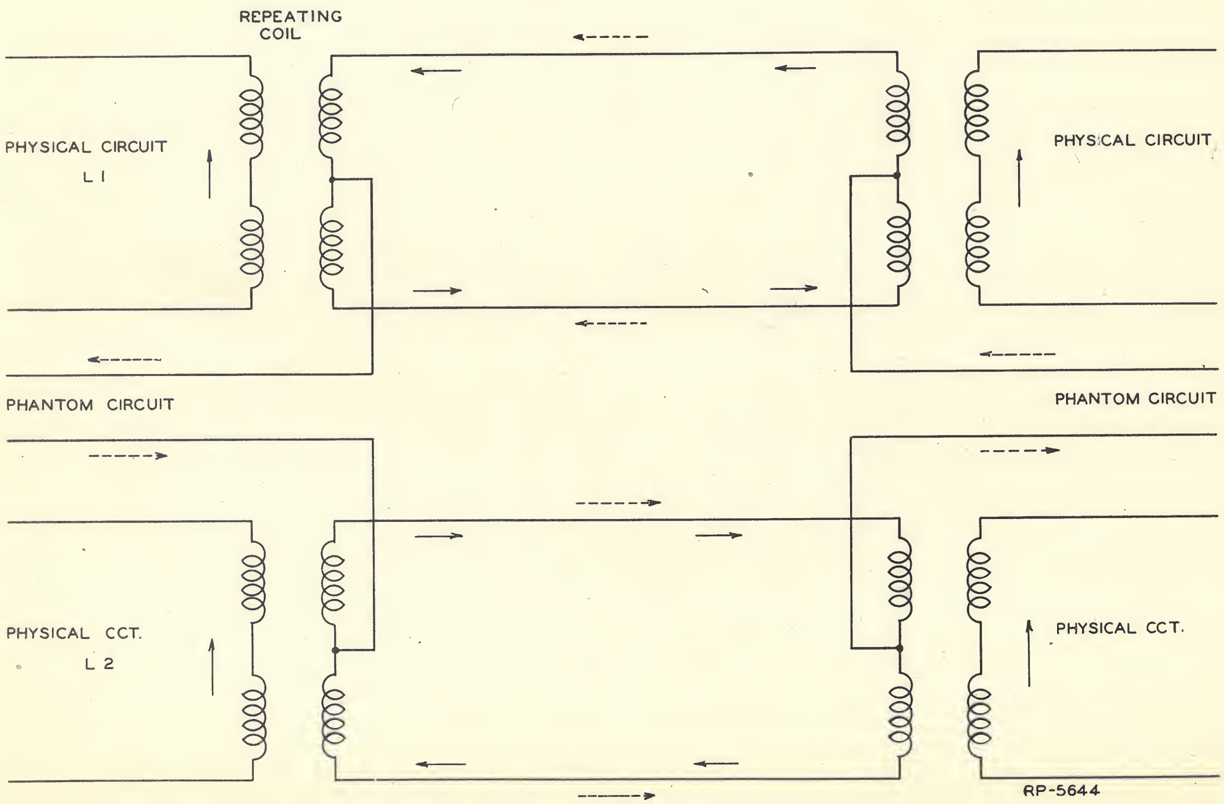


Fig. 105

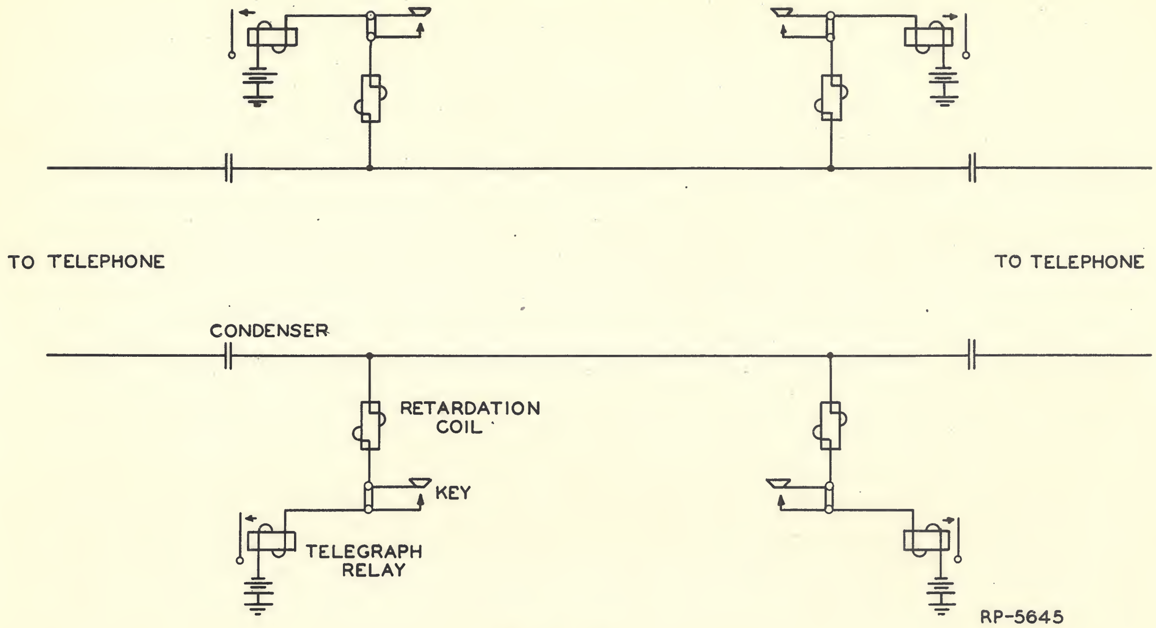


Fig. 106

frequency telegraphic currents. Such a scheme is illustrated in Fig. 106. The high frequency voice currents from the telephone pass through the condenser very easily but do not go to ground through the telegraph relay due to the insertion of the retardation coil in this circuit. With this combination, one telephone conversation and two telegraph messages can be sent over a pair of wires without interference.

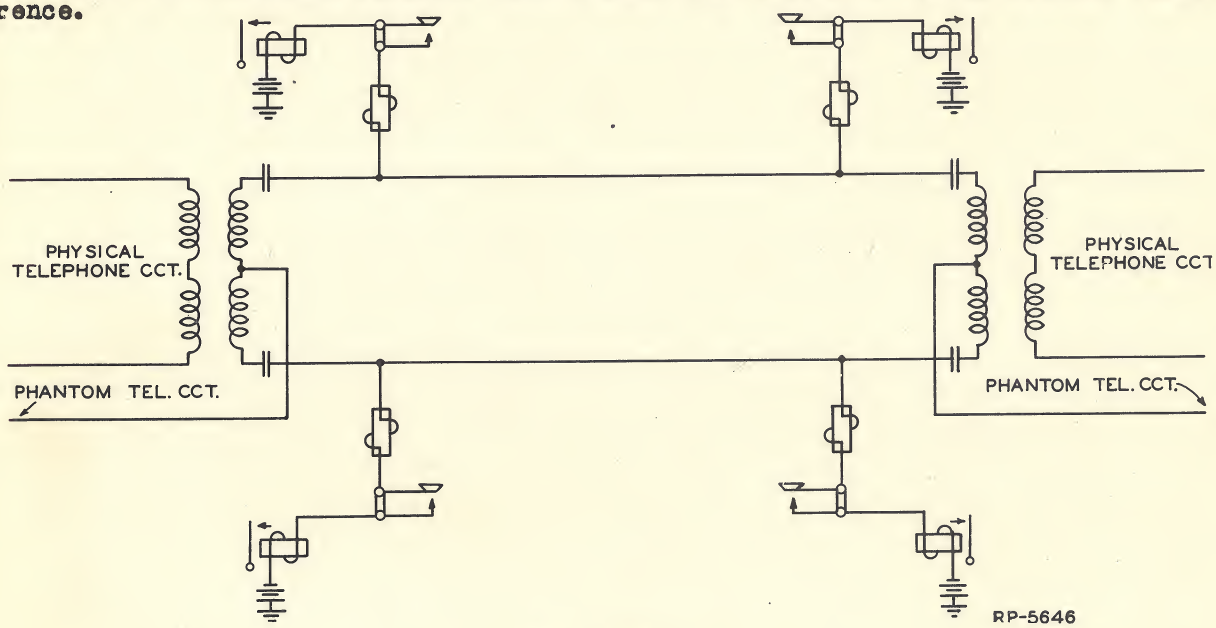
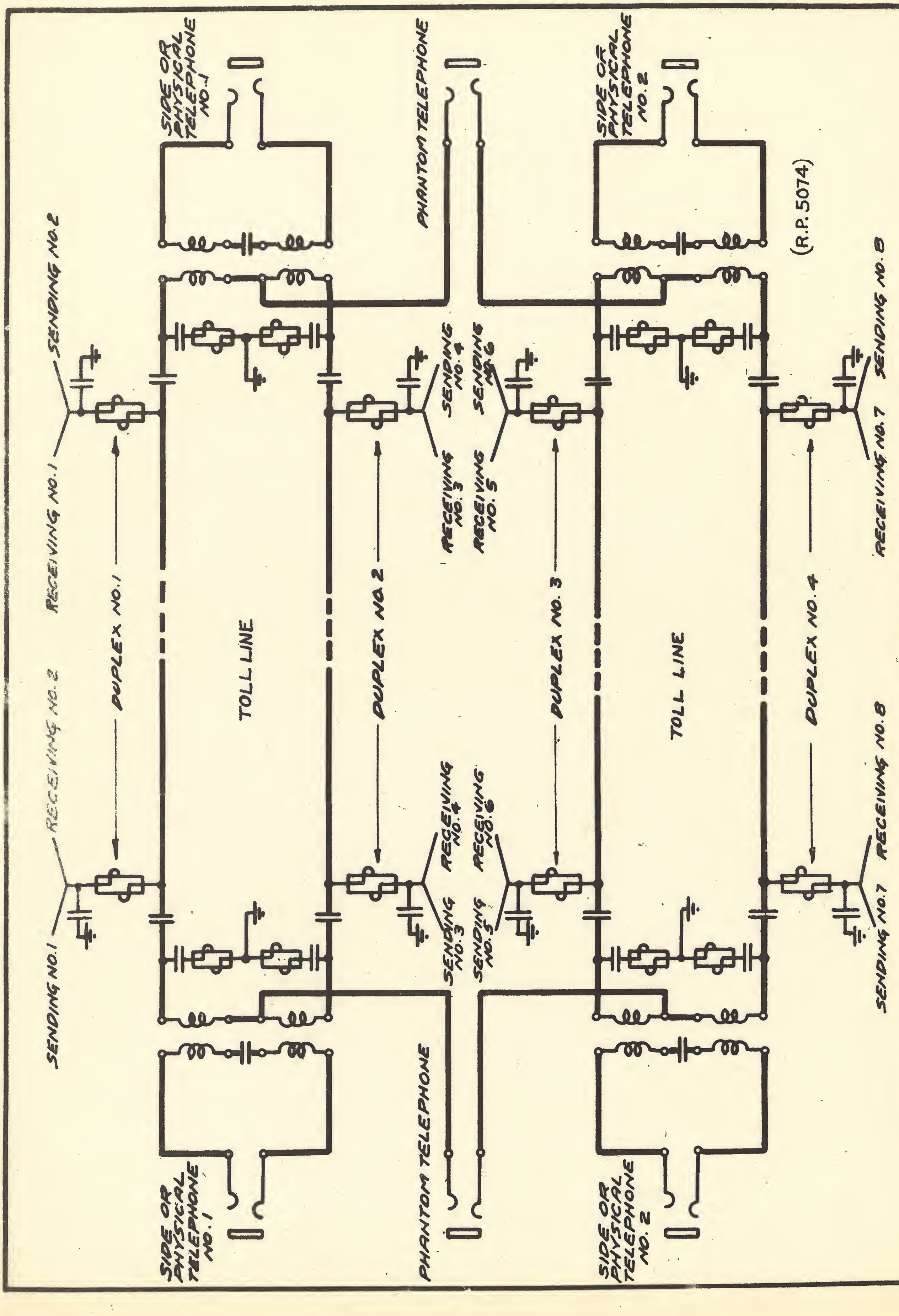


Fig. 107

In Fig. 107 is shown the composite circuit to which has been added the repeating coils required for superimposing a phantom circuit on the line. The number of telegraph circuits which may be provided can be doubled by so arranging the circuits that a telegraph message can be sent in each direction simultaneously over each wire. This scheme is what is known as a "duplex" telegraph circuit but will not be taken up in detail here.

LESSON VIII



MAXIMUM USE OF 4 CONDUCTORS - 2 SIDE OR PHYSICAL TELEPHONES, 1 PHANTOM TELEPHONE, 4 TELEGRAPH CKTS. EACH DUPLEXED GIVING 8 1 WAY TELEGRAPH CKTS.

FIG. 108

CHAPTER VIII

In Fig. 108 we have then a complete phantom and composite circuit duplexed, providing 3 telephone circuits and 8 telegraph circuits on 4 wires.

We are now ready to consider another scheme which has been developed in recent years for making even greater use of telephone lines than was possible, using the phantom and composite arrangement. This is the carrier current scheme. In this scheme voice currents are superimposed upon a high frequency current and the whole transmitted over the telephone wires. At the distant end the high frequency current is taken out, leaving the original voice current. It is possible to transmit a number of conversations simultaneously in this way by superimposing each voice current on a different frequency, as the various frequencies can be separated at the receiving end. This scheme is not materially different from the ordinary scheme of radio broadcasting.

You are all familiar with the fact that various stations broadcast at different frequencies and that any station can be selected by tuning the radio receiving set to that particular frequency. This is the scheme that is used in carrier current telephone systems except that the frequencies are very much lower and the amount of power transmitted is very small. The high frequency current used to superimpose the voice current on is called carrier current as it carries the voice frequency, hence the name "carrier system".

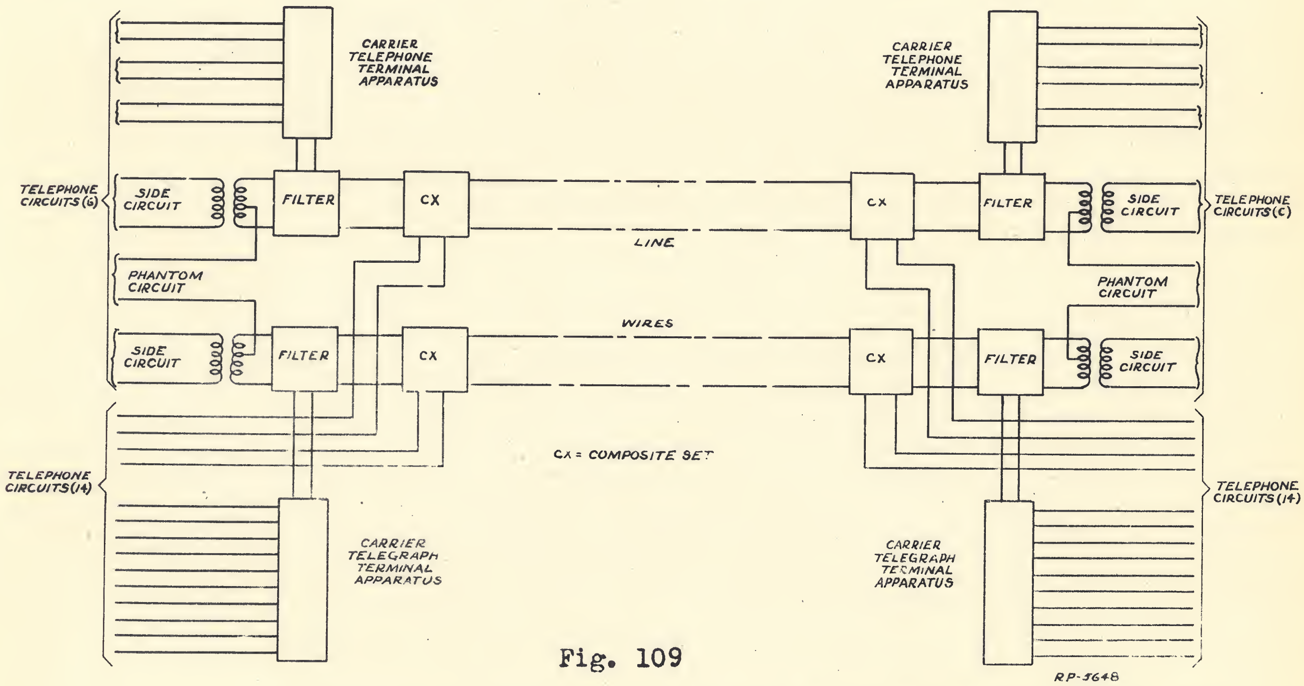


Fig. 109

It is also possible to use this same scheme for telegraph messages, and in Fig. 109 are shown two pair of wires with the 3rd telephone circuit provided by means of the phantom, 10 carrier telegraph channels in addition to 4 telegraph channels provided by means of composite circuits, making a total of 14 telegraph circuits. In addition, 3 carrier telephone circuits are provided which, added to the physical and one phantom circuit, makes a total of 6.

The frequencies used for carrier telegraph and telephone circuits are of interest and are shown in Fig. 110. It will be noted that a fairly wide band

of frequency is allotted each carrier telephone circuit as it is necessary in order to prevent interference to provide a band which will cover practically the whole range of voice frequencies from the low notes to the high notes. In contrast, the telegraph channels are confined to a very narrow band of frequencies.

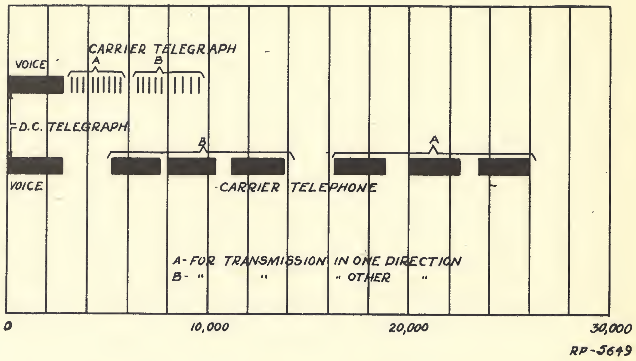


Fig. 110

In Fig. 111 is shown what might be called the evolution of a carrier telegraph system. It is intended to show by simple examples in Figs. 111-a, b, c, and d, the functions of the parts of a simple carrier system. In each system the signal being transmitted is the letter "a" (dot dash) and this signal is shown in various steps of the transmission in each system. A

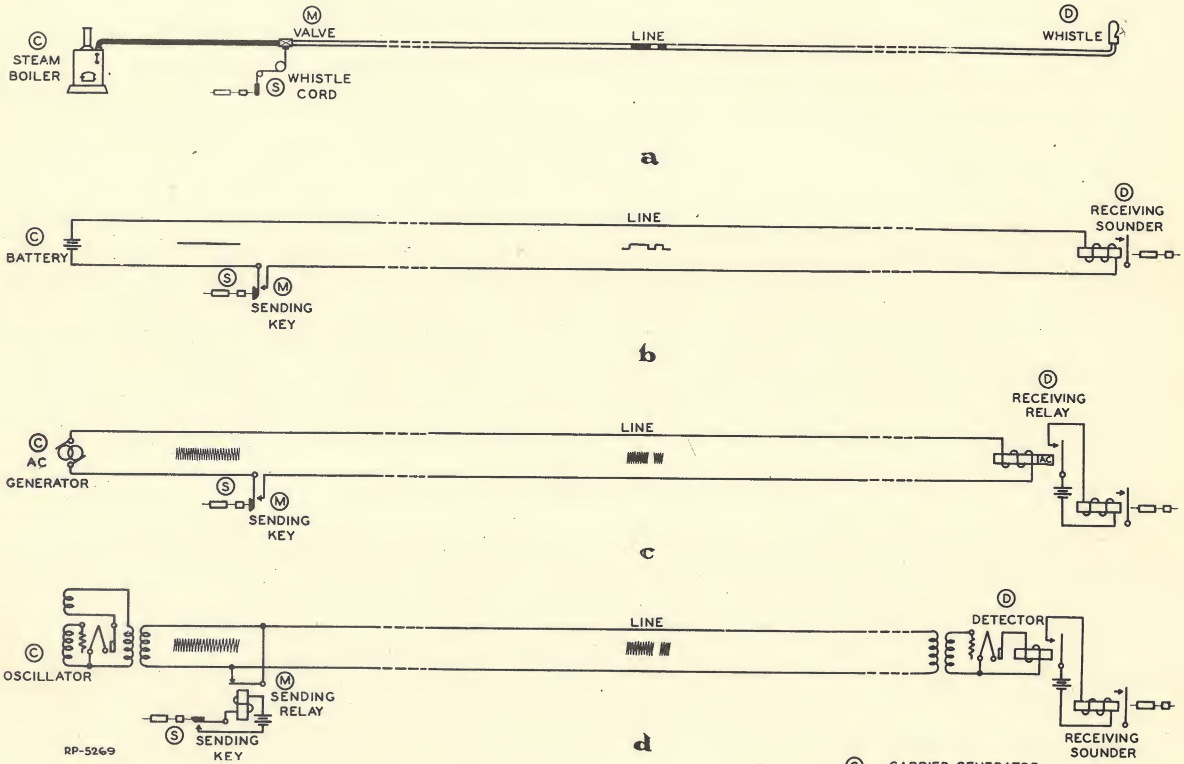


Fig. 111

carrier telegraph system is fairly simple as the signals are transmitted by complete interruptions of the circuit forming the dots and dashes of the various letters. Telephone conversation, however, produces a variation in the signal current and not a complete interruption. What we need is a device that will vary the flow of carrier current in accordance with the voice signal. We all understand how the resistance of the carbon button in a transmitter varies with the voice waves, and thus varies the flow of direct current in the circuit.

CHAPTER VIII

The evolution of the carrier telephone system from this fundamental principle to the carrier system is shown in Fig. 112. The fundamental telephone

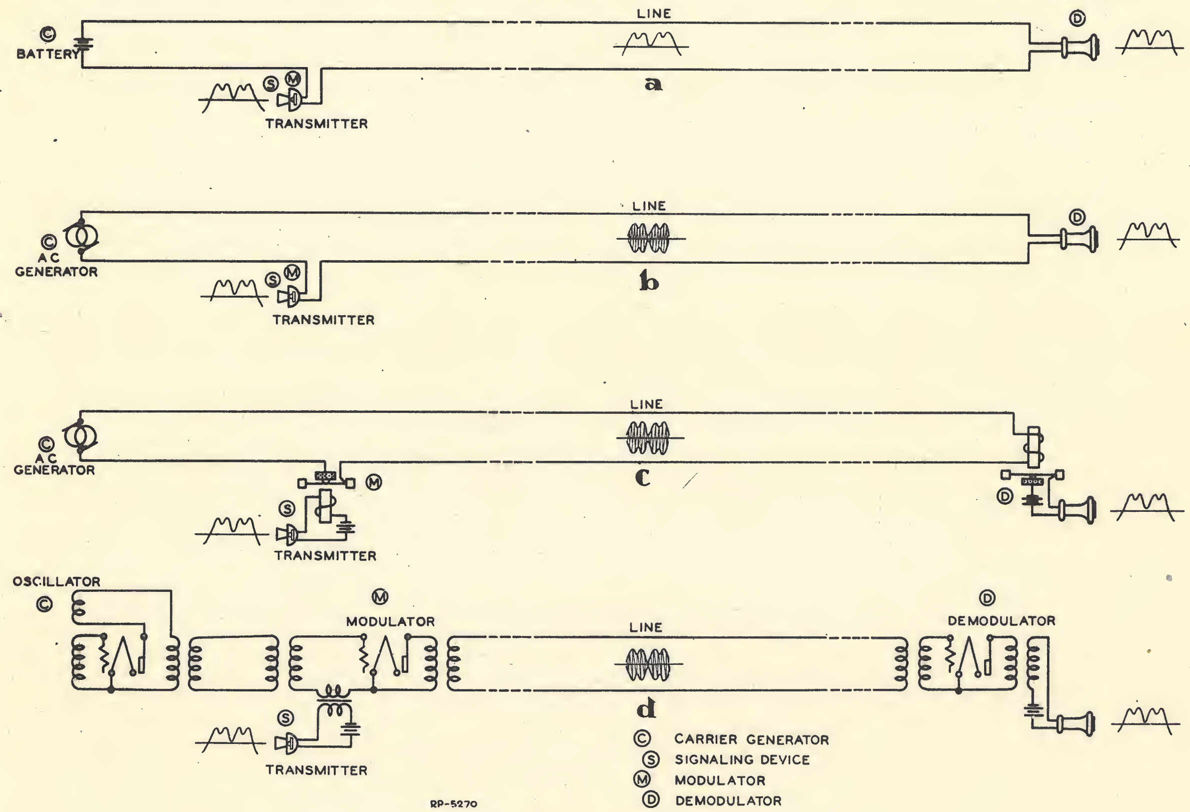


Fig. 112

circuit is shown in "a". In "b" an alternating current generator has been inserted in place of the battery so that we have a varying alternating current instead of a varying direct current. In Fig. "c" we have a circuit for accomplishing the same result by a little different arrangement, using local battery in series with the transmitter and receiver. Fig. "d" accomplishes the same thing except that the alternating current generator has been replaced by a vacuum tube oscillator which is merely another means for generating a high frequency alternating current. Another vacuum tube is used as a modulator which is merely a more efficient means for causing the high frequency alternating current to vary in response to the voice currents. The demodulator at the receiving end operates in the same manner as a detector tube in a radio receiving set for taking out the high frequency carrier current, leaving the voice frequency current.

In Fig. 113 is shown some carrier equipment mounted on racks for actual use in the telephone office.

In any long distance telephone line a considerable amount of energy is dissipated in the line itself due to line resistance and leakage, thereby limiting the distance over which it is possible to carry on intelligent conversation. In order to extend the range over which telephone conversation is practical, devices known as telephone repeaters are inserted at certain points in a line, thus in-

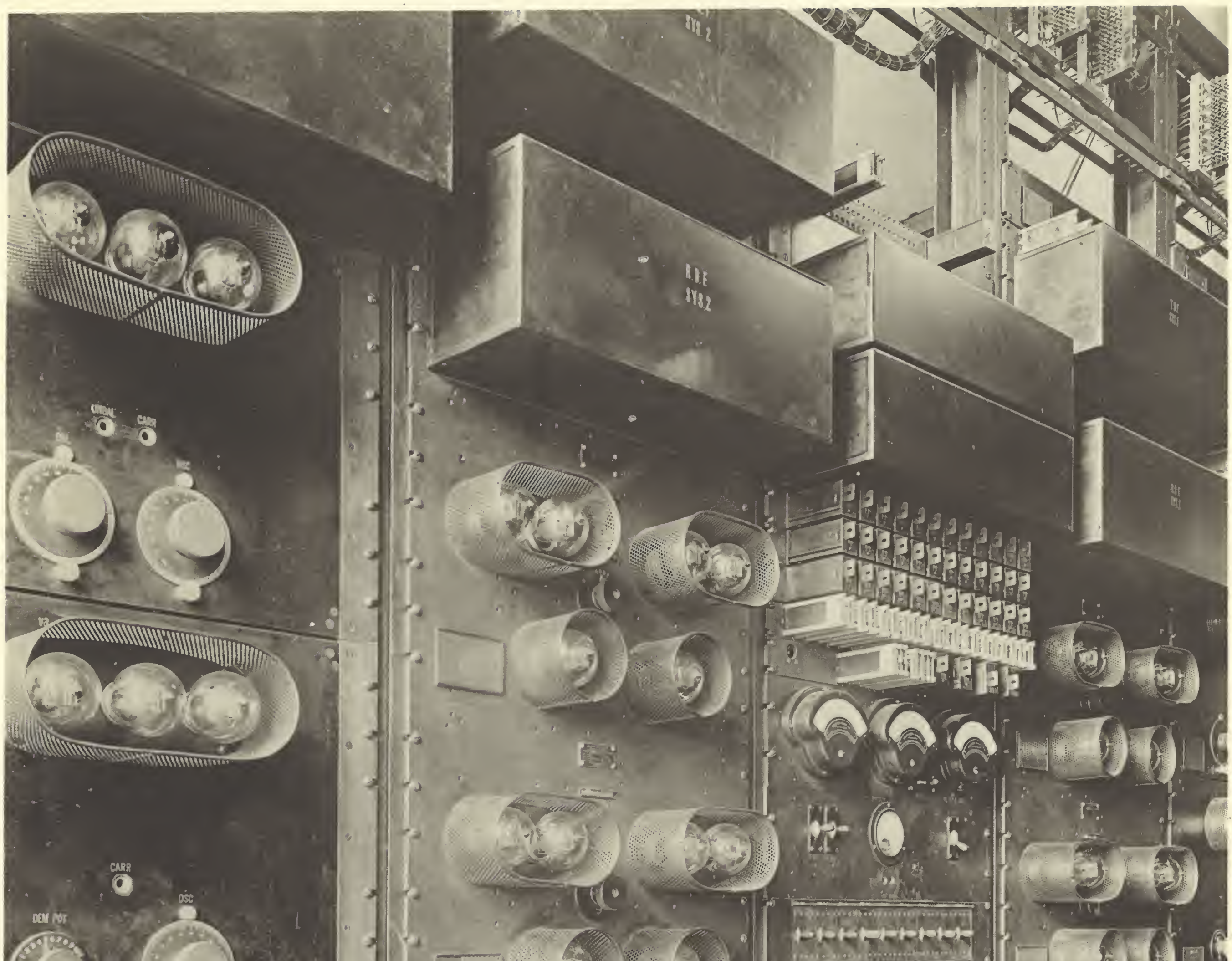


Fig. 113

creasing the range of telephonic transmission indefinitely. The essential part of the modern repeater is the vacuum tube and its operation as a repeater is exactly similar to the audio amplifying stages of the ordinary radio receiving set.

In Fig. 114 is shown a simple diagram of the circuit used with a repeater bulb. The filament when heated by the current from the battery marked "A" emits electrons which, according to the theory, are negative charges of electricity. The "plate" is connected to the positive side of the battery marked "B" and the negative electrons are attracted to this positive plate. This action constitutes an electric

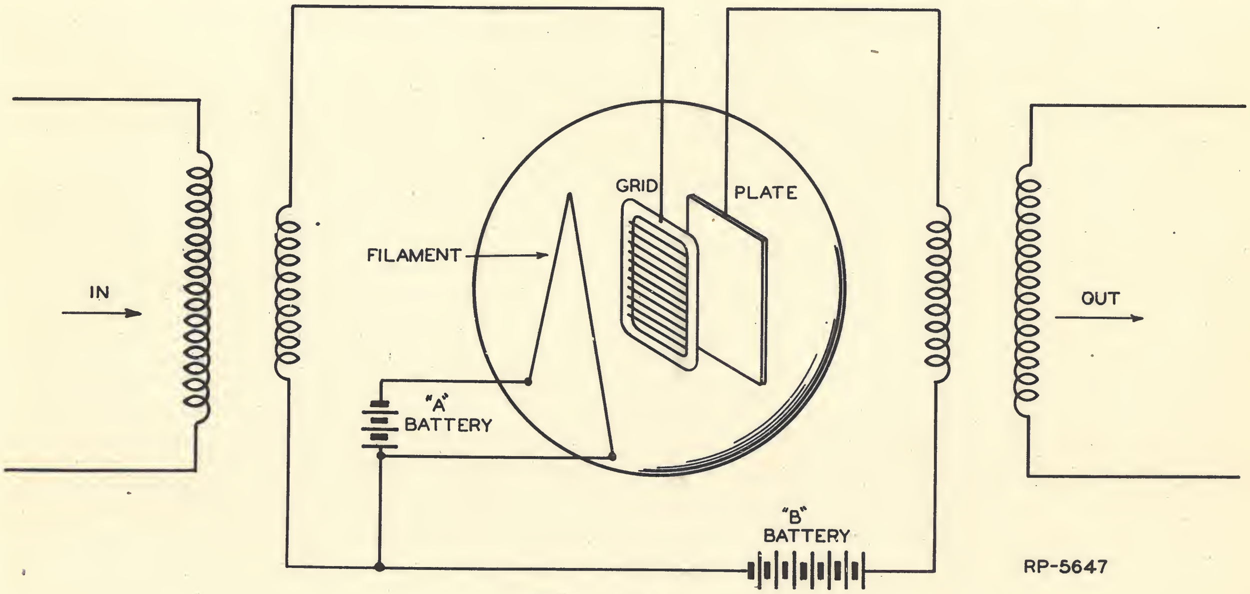


Fig. 114

current flowing in the plate circuit back to the filament. It was further found that by placing a third element between the filament and the plate known as the "grid", and by varying the negative charge on this element, the number of electrons flowing between the filament and the plate could be caused to vary. This seems the natural thing to expect in view of the fact that,as we have already learned, magnets of unlike polarity attract and those of like polarity repel. Thus, the negatively charged grid repels the electrons which are negative charges of electricity. It was soon found that by varying the negative charge on the grid, the flow of electrons and the resulting electric current in the plate circuit would vary in exactly the same way. It was then a very simple matter to impress upon the grid by means of a repeating coil as shown in the left-hand side of the circuit, a voice current. As the voice current varied, the negative charge on the grid varied which produced a corresponding change in the plate current. The plate circuit having a repeating coil in it, produced a current in the output side of this circuit. It was found that a very small change in the charge on the grid would produce a considerable change in the plate current so that a very weak voice current would produce a large fluctuation in the current of the plate circuit. This increased fluctuation of the voice currents is equivalent to adding greater strength to the voice currents or amplifying them. One tube will amplify the voice currents equivalent to the loss in about 18 or 20 miles of toll cable and their use

on toll lines has made possible the present long distance transcontinental lines.

In Fig. 115 is shown diagramatically the amplification of a telephone current by means of repeaters from Boston to San Francisco. It will be noted that in this circuit the voice currents have been amplified 13 times at various points along the way. It is hard to conceive the enormous loss in power which takes place along a telephone line. The dotted line extending upward between Sacremento and San Francisco will give some idea of the power that will have to be put into the line at Boston to give the same amount of power at San Francisco if no repeaters were used in the circuit. The power necessary would be indicated at the point where this dotted line intersects the vertical axis. Actually, this will be several million kilo-watts - more than is delivered to the entire earth by the sun. By the use of repeaters we get the desired amount of power at San Francisco, without the power at any point in the circuit exceeding a small fraction of a watt.

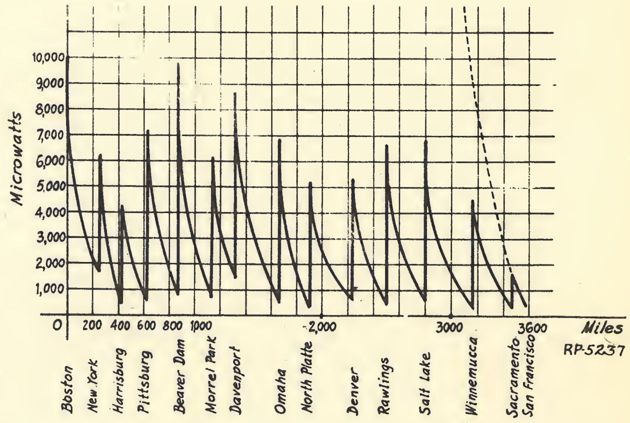


Fig. 115

In Fig. 116 is shown a typical installation of telephone repeaters. (See page 15.)

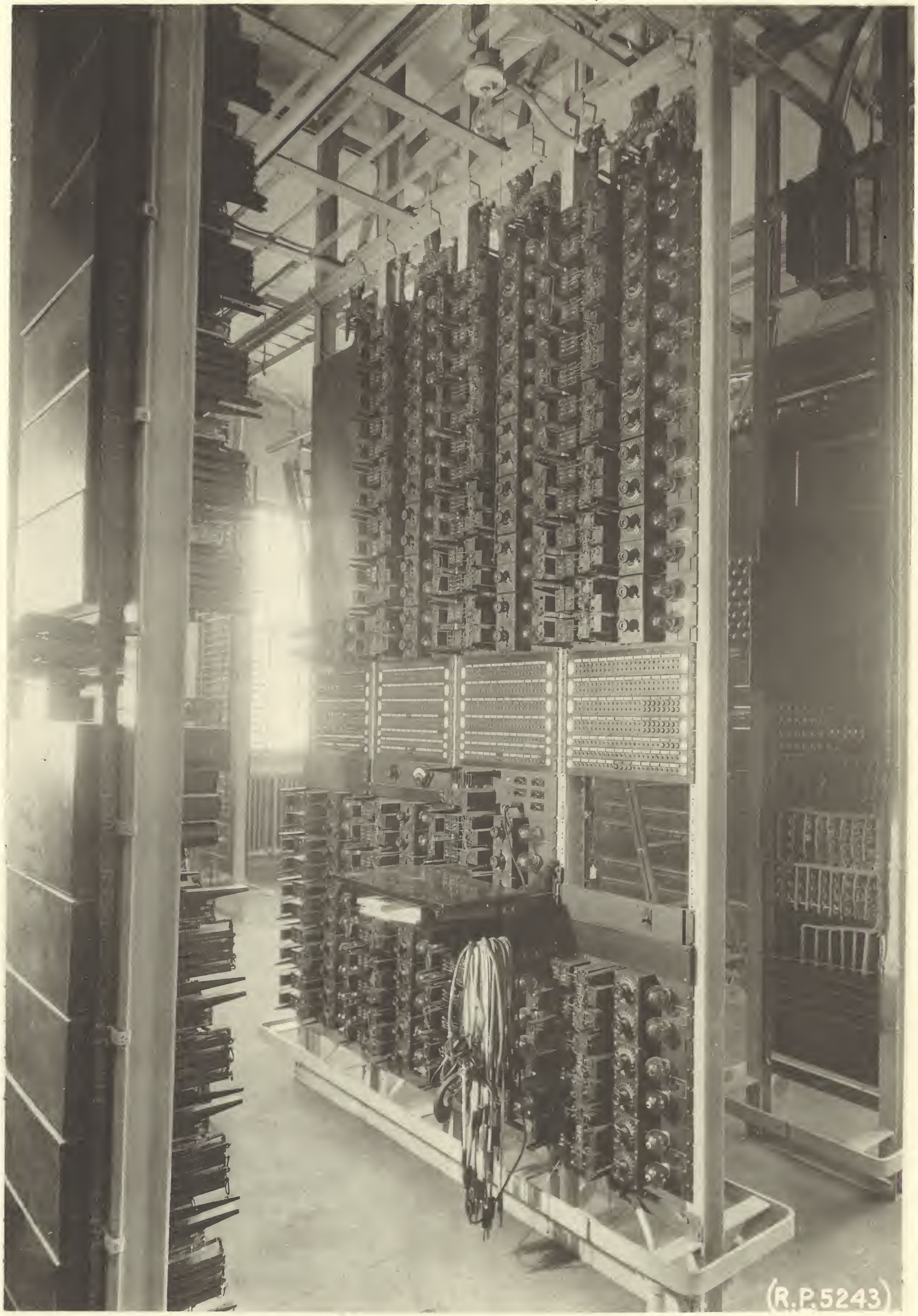


Fig. 116

150.
12/1800
12
60

150
30
6500
4
130
60/1800